United States Air Force
Scientific Advisory Board

Report on

Air Force Command and Control: The Path Ahead

Volume 2: Panel Reports

SAB-TR-00-01
March 2003

Cleared for Open Publication

This report is a product of the United States Air Force Scientific Advisory Board Committee on *Air Force Command and Control: The Path Ahead*. Statements, opinions, recommendations, and conclusions contained in this report are those of the committee and do not necessarily represent the official position of the U.S. Air Force or the Department of Defense. This report is reflective of the status of Air Force policy, organization and programs as of the summer of 2000.

United States Air Force
Scientific Advisory Board

Report on

Air Force Command and Control: The Path Ahead

Volume 2: Panel Reports

SAB-TR-00-01
March 2003

Cleared for Open Publication

(This Page Intentionally Left Blank)

Foreword

This volume presents the deliberations and conclusions of the individual panels making up the 2000 Air Force Scientific Advisory Board (SAB) Summer Study, "Air Force Command and Control: The Path Ahead." In this study, the Board was asked to assess the command and control system and the supporting communication and information systems; to consider technical and process improvements and to make recommendations on what should be done to "have the Air Force linked by 2005"; and to build toward the Air Force's long-term command and control goals. There are two volumes to the report. Volume 1 presents a brief summary of the findings and the major recommendations. This volume, Volume 2, presents the panel reports, including detailed findings and recommendations.

The study results are the product of a substantial effort by a skilled team, including panels led by experts in their assigned area. The study leadership wishes to thank the many individuals and organizations in Government and industry who contributed to the deliberations and conclusions presented. In addition to SAB members, many ad hoc members devoted their time. Air Force Major Air Command liaison officers were extremely helpful in our research and deliberations, as were the technical writers provided by the Air Force Academy. In addition, both the liaison officers and the technical writers provided outstanding administrative and logistics support. We gratefully acknowledge the contributions and guidance of our General Officer Participant, General John Jumper, Commander, Air Combat Command; and Major General Gerald Perryman, Jr., Commander, Aerospace Command and Control and Intelligence, Surveillance, and Reconnaissance Center.

The study leaders would also like to give special recognition to the SAB Secretariat and support staff, in particular to Capt D. Brent Morris, the Study Executive Officer; and to Ms. Kristin Lynch of the ANSER team, who provided invaluable administrative and editing assistance in the preparation of graphics and the publication of the report.

We believe that through the dedication of the current leadership, the Air Force has the greatest opportunity ever in developing an effective and efficient theater command and control system, and we encourage every Air Force member to seize this opportunity.

Finally, this report reflects the collective judgment of the SAB and hence is not to be viewed as the official position of the United States Air Force.

Peter R. Worch

Dr. Peter R. Worch
Study Chair

James P. McCarthy

Gen James P. McCarthy, USAF (Ret)
Study Vice Chair

(This Page Intentionally Left Blank)

Executive Summary

For more than three decades, the Air Force has scrutinized command and control (C^2) modernization planning, programs, training, procedures, and architectures and has identified repetitive C^2 problems in each decade.

The Air Force Chiefs of Staff (CSAFs) have chartered numerous studies and conducted four-star reviews in their attempts to fix the Air Force C^2 problem. These CSAF studies began with the 1986 Air Force Studies Board Summer Study; this was, in turn, followed by the 1992 and 1993 Command, Control, Communications, Computers, and Intelligence Broad Area Reviews, the 1996 Air Force Scientific Advisory Board (SAB) Summer Study, the 1997 C^2 Task Force, the 1997 C^2 Four-Star Summit, and this 2000 SAB C^2 Summer Study. The Air Force Chiefs of Staff also established a new Air Staff C^2 Directorate, an Air Staff C^2 General Officer Steering Group, and the Aerospace C^2 Intelligence, Surveillance, and Reconnaissance Center (AC2ISRC) in their attempts to fix C^2.

The redirection of this year's SAB Summer Study from "limited forward basing" to "command and control" reflects the Chief of Staff's strong desire to improve Air Force C^2 capability. Each study made recommendations for fixing the problems the Air Force was having with C^2. Analysis of the recommendations indicates that the same recommendations were made many times, yet the Service is not achieving the vision of linked Air Force command centers that are able to collaborate globally in support of all commanders in chiefs (CINCs), Services, allies, and the Aerospace Expeditionary Force.

The lessons learned from DESERT STORM and ALLIED FORCE and the results of every SAB and Defense Science Board study have determined that U.S. aerospace power capabilities continue to outperform the associated C^2 capabilities. In theater C^2, this is particularly evident in time-critical targeting, battle damage assessment, and campaign assessments.

The Tasking

The Air Force is not on a path that provides coherence across space, air, and land assets to support the timeliest and effective decision-making and execution. Thus, the Board was asked in the Terms of Reference (Appendix A) to

- Assess the C^2 system and the supporting communication and information systems
- Consider technical and process improvements and make recommendations on what should be done to "have the Air Force linked by 2005"
- Build toward the Air Force's long-term C^2 goals

The specific tasks are shown below; each task had a panel to address it. Panel membership is in Appendix C. The SAB was to

- Define the Air Force C^2 system with today's capabilities and identify alternatives to enhance C^2 over time
- Define interoperability (joint and coalition) to ensure coordinated efforts on the battlefield
- Identify the technologies that can enhance present and future C^2 systems, with near-term emphasis on timely and effective communication

- Assess the acquisition, programmatic, and cost-effectiveness issue
- Consider the organizational, personnel, training, and support consequences

And we added a Bridging and Vision Panel.

A Framework for Solution

The Study recognized the many past organizations, directives, studies, and other efforts to develop a theater C^2 system for the Air Force. Many dedicated and talented leaders have made great efforts, and even great strides, in the name of C^2. Yet we once again find ourselves on the doorstep with a basketful of comments and ideas to improve the C^2 of Air Force combat operations.

It is our belief that the solution set can, and should, be cast in a framework in order to capture the underlying rationale for the suggestions. Our *framework* includes the following elements:

- A unified, understood, focused approach to C^2
- A process, driven by the concept of operations and based on capabilities, that encourages, not impedes, system operational enhancement
- Acquisition processes that are timely and efficient in capturing emerging technologies
- Taking the lead in becoming more interoperable, including joint and coalition operations
- Horizontal integration of intelligence, surveillance, and reconnaissance (ISR) with C^2
- Focus and follow-through

Recommendations

We recommend that the following actions be taken:

Recommendation 1. Emphasize the Role of Command and Control in the Air Force

It is important that *all* levels of the Air Force, as well as Congress and other Government entities, understand the criticality of effective C^2 to the outcome of a crisis.

Recommendation 2. Manage Theater Command and Control as an Integrated Set of Weapon Systems

When an Air Force system (for example, the F-15E) is officially designated a weapons system, a certain formality in the management of that system, including people, hardware, software, training, certification, maintenance, and evolution, is established and implemented. C^2 systems deserve nothing less.

Recommendation 3. Strengthen the Air Operations Center (AOC) Through Restructuring, Staffing, and Training

Though the AOC is at the heart of precision air operations, recent conflicts have been characterized as a “pickup game” of equipment and personnel. Consequently, the efficiency and success of these air operations have suffered. An effective and efficient AOC, ready to deploy or operate from home at any time, is absolutely essential.

Recommendation 4. Field and Evolve the Theater Battle Management Core System (TBMCS)

TBMCS has been a major, albeit painful, step to a new integrated theater C^2 system. Though it cannot be considered a final configuration with all modules in optimum operation, it is a major step forward from the previously fragmented system(s). It is time to accept the system and to accept the fact that continual upgrades will be needed to meet operational requirements and technology advances; the upgrades should be so planned.

Recommendation 5. Institutionalize a C^2 Evolutionary Integration Process

The major difficulty in taking advantage of developments from the military and commercial sectors—including off-the-shelf solutions, as well as those successfully prototyped in laboratory or field exercises—has been the lack of a formal and cyclical means to integrate new capabilities online. The Air Force should create and support a process for the evolutionary integration of developed modules.

Critical to effective integration and management is the creation of a partnership, based on mutual support and trust, of the operators (for example, AC2ISRC); the developers (for example, the Electronic Systems Center [ESC] or Air Force Research Laboratory); the integrators (for example, ESC); and the operational testers (for example, the Air Force Operational Test and Evaluation Center), each of which must accept and carry out its responsibilities.

Recommendation 6. Enable and Encourage Rapid Technology Insertion

The Study determined that there are no technology impediments to substantial improvements in the effectiveness and efficiency of air operations C^2. With some exceptions, in which additional operational focus is needed, the emphasis must be on the timely and effective transition of military and commercial technologies to the Air Force C^2 system needs. The Air Force should follow a focused effort to improve technology exploitation. A C^2 testbed is essential to fostering rapid development of the AOC and other elements of theater C^2.

Recommendation 7. Achieve Information Interoperability for Warfighters Through the Joint Battlespace InfoSphere (JBI)

The opportunity to significantly improve our ability to conduct effective joint and coalition warfare rests on the degree of interoperability of the C^2 processes. The Air Force should seize the initiative to evolve the JBI (see Chapter 8) as the basis for true interoperability. Many specific nearer-term problem fixes are also important and possible.

Recommendation 8. Staff and Train to Be Consistent With the Importance of C^2

The Air Force has been a pioneer in recognizing the importance of its people. At the heart of this recognition, and built on the foundational element of "quality people" for the Air Force core competencies, is the establishment of a trained force of C^2 professionals.

Recommendation 9. Strengthen Efforts for Attack of Time-Critical Targets

Recent crises have again highlighted the shortfall in the capability for rapid acquisition, identification, and attack of mobile targets. Clearly, the delays in the process are unacceptable,

and progress in the improvement has been marginal. The Air Force should establish a program team to address the rapid-response attack of time-critical targets.

Recommendation 10. Facilitate and Enhance Data Connectivity

Critical to the dynamic management of combat airpower is the data connectivity from C^2 activities to the aircraft. The delays in fielding solutions to the aircraft datalink problem seem to be more political than technical. The Air Force should exercise leadership in achieving the goal of interlinking aircraft based on operational access to message sets (J-series) rather than emphasizing only specific equipage.

Summary

The essence of the recommendation set is to provide focus and follow-through on C^2 issues from a very high level. They key actions are to

- Establish a single C^2ISR manager at the Air Force level (for example, a three-star operator)—an Air Force Council Member.
- Integrate expert information technology professionals (internal and new) into the C^2 staff.
- Direct a C^2 program restructuring.
- Adopt the Global Command and Control System (GCCS) framework: evolve theater Air Force C^2 applications into GCCS-AF.
- Direct a capability-centric evolutionary integration process for $C^{2.}$
- Manage theater aerospace C^2 as a system of weapon systems.
- Baseline the number, configuration, and location of AOCs. Enhance operation and reduce personnel through daily "wartime" use.
- Appoint a "lead dog" for agile combat support software systems (Global Combat Support System-Air Force).

The Air Force vision of "well-equipped C^2 centers collaborating globally in support of the CINCs" can be rapidly achieved if senior Air Force leadership strongly endorses the need for an enterprise-wide C^2 capability. The Air Force must restructure the way C^2 programs are managed and resourced, and at every opportunity leadership must clearly speak out about their dedication to achieving an enterprise-wide C^2 capability. In this report we have provided a proposal for how the Air Force can achieve an enterprise-wide C^2 capability by 2005. We have provided our views on areas that the Secretary of the Air Force, Air Staff, and major command staffs should focus on in starting down a C^2 modernization journey. The journey of achieving an effective distributed, collaborative, enterprise-wide C^2 capability that allows C^2 centers to collaborate globally in support of the CINCs is one of the most important journeys the Air Force must take in the 21st century.

Table of Contents

Foreword.......... iii

Executive Summary.......... v

List of Figures.......... xi

List of Tables.......... xii

Chapter 1 Introduction.......... 1-1

Chapter 2 Concept and System Definition Panel.......... 2-1
Appendix 2A C2 System Definition and Operational Concept Panel Charter.......... 2-29
Appendix 2B C^2 Concept and System Definition Panel Membership.......... 2-31
Appendix 2C C^2 Concept and System Definition Panel Visits.......... 2-33
Appendix 2D C2 Weapons System Management—"Matrix Table" 2-35

Chapter 3 Report of the Interoperability Panel.......... 3-1
Appendix 3A Interoperability Panel Charter.......... 3-43
Appendix 3B Interoperability Panel Membership.......... 3-45

Chapter 4 Report of the Technologies Panel Technology Investment for Future Capabilities.......... 4-1
Appendix 4A Technology Panel Charter.......... 4-25
Appendix 4B Technology Panel Membership.......... 4-27
Appendix 4C Defense Information Infrastructure Common Operating Environment (DII COE).......... 4-29

Chapter 5 Report of the People and Organization Panel.......... 5-1
Appendix 5A People and Organization Panel Charter.......... 5-25
Appendix 5B People and Organization Panel Membership.......... 5-27
Appendix 5C Available C^2 Training Opportunities.......... 5-29
Appendix 5D Risk-Based Decision Support Systems for Commanders *Elisabeth Paté-Cornell*.......... 5-31

Chapter 6 Report of the Acquisition and Program Management Panel.......... 6-1
Appendix 6A Acquisition Panel Charter.......... 6-37
Appendix 6B Acquisition and Program Management Panel Membership.......... 6-39

Chapter 7 Linking The Air Force By 2005.......... 7-1

Chapter 8 Technology and Architecture Issues in Implementing the Joint Battlespace InfoSphere (JBI).......... 8-1

Chapter 9 Summary.......... 9-1

Appendix A to Volume 2 Terms of Reference.......... Appendix A-1

Appendix B to Volume 2 Acronyms and Abbreviations.......... Appendix B-1

Appendix C to Volume 2 Study Organization.......... Appendix C-1

Appendix D to Volume 2 Top Level Organizations Visited.......... Appendix D-1

Appendix 4D Information Assurance.......... Appendices 4-3

Appendix 4E Revolution In Battlefield Awareness Of Advanced Ground Moving Target Radar.......... Appendices 4-9

Appendix 6C The Current Air Force Acquisition Process for C^2 Systems: A Case Study of TBMCS ..Appendices 6-3

Appendix 6D GCCS Integration Process..Appendices 6-9

Appendix 6E GCCS Mission Applications Schedules ....Appendices 6-11

Appendix 6F GCCS Mission Applications Abstracts...Appendices 6-13

Appendix 6G The DII COE (from the I&RTS, v. 4.0) ....Appendices 6-55

Appendix 6H GCSS-AF The Way Ahead (Volume 1)..Appendices 6-67

Appendix 6I GCSS Capstone Test and Evaluation Master Plan (TEMP) ....Appendices 6-96

Appendix 6J DODIIS Test Process ....Appendices 6-97

Initial Distribution

List of Figures

Figure 2-1. *The Global Engagement Arch* 2-3
Figure 2-2. *Expeditionary Aerospace C2 System Centers* 2-7
Figure 2-3. *Existing C2 System Architecture* 2-10
Figure 2-4. *Planning and Execution Management* 2-11
Figure 2-5. *CAOC/AOC C2 System Operational Relationship* 2-13
Figure 2-6. *Proposed AOC Joint Organizational Structures* 2-14
Figure 2-7. *GCCS-AF* 2-25
Figure 2-8. *Contrasting Styles of Design* 2-27

Figure 3-1. *Pervasive Needs for Interoperability Throughout a Joint/Coalition Force* 3-2
Figure 3-2. *Interoperability Has Many Dimensions* 3-5
Figure 3-3. *A Hierarchy of Levels of Interoperability Illustrates Its Complexity* 3-7
Figure 3-4. *Three Views That Define an Architecture* 3-14
Figure 3-5. *CJCSI 6212.01B Establishes a Process for Assessing and Certifying the Interoperability of a Developmental System* 3-23
Figure 3-6. *The Traditional Linear "Big Bang" Approach to Delivering Military Capability Should Evolve to One Linking the Development Spiral to Refinement of CONOPs and Concepts* 3-28
Figure 3-7. *Technology Will Increasingly Allow Automated Processes that Aggregate Data into Information, Interpret Information to Create Knowledge, and Disseminate Knowledge to Allow Shared Understanding* 3-29
Figure 3-8. *The Progression, as Technology Advances, from Data to Understanding* 3-30
Figure 3-9. *The Evolution from Platform-Centric to Information-Centric Operations* 3-31
Figure 3-10. *Technical and Operational Dimensions of Information-Centric Operations Come Together in Networking, Information, and Knowledge Environments that Support Warfighters at All Echelons* 3-32
Figure 3-11. *Demonstrations, Experiments and Exercises Are Key Elements of Integrating Operational and Technical Solutions to Produce New Capability* 3-33
Figure 3-12. *Commercial Layered Architectures Point the Way to Interoperability in* C^2 3-35
Figure 3-13. *The JBI Greatly Simplifies the Specification and Assessment of Interoperability* 3-38

Figure 4-1. *Available Technologies* 4-3
Figure 4-2. *New Sources of Technology* 4-22

Figure 5-1. *Subject areas investigated by the People and Organization Panel* 5-1
Figure 5-2. *Disparity in AOC Functional Organizations Based on Air Force Publications*" 5-4
Figure 5-3. *Human-System Interface Contribution to Interoperability* 5-9
Figure 5-4. *The* C^2 *NAF Concept* 5-17
Figure 5-5. *Elements Enabling the Professional* C^2 *Warrior Force* 5-19
Figure 5-6. *The Professional Aerospace Warfighter Track* 5-20
Figure 5-7. *Expanded Capability for Tracking of Personnel Skills and Experience* 5-21
Figure 5-8. *Human–System Integration Development Process* 5-22

Figure 6-1. *Major Decision-making Support Processes in the Department of the Navy* 6-10
Figure 6-2. *Navy C2 Organization* 6-15
Figure 6-3. *GCSS-AF Information Cube* 6-20
Figure 6-4. *Testbed Team Responsibilities* 6-28
Figure 6-5. *Evolutionary Integration* 6-29

Figure 7-1. *TCT Targeting Timeline – Now and Future* 7-2
Figure 7-2. *Envisioned Datalink Architecture* 7-9
Figure 7-3. *J-Series Datalinks Planned For Installation in AF Aircraft (per JTDLMP)* 7-10
Figure 7-4. *Datalink Equipped Aircraft Under Current And Alternate Installation Schedules* 7-11

Figure 8-1. *The Basic Structure and Primary Functions of the JBI* 8-3
Figure 8-2. *The Basic Layered Structure of the Common Operating Environment* 8-6

Figure 8-3 *The JBI Shared Information Repository Deals with Many Warfighting and Support Communities and Supports Tailored Information Products at All Force Echelons* 8-8
Figure 8-4. *Structure and Features of a Notional JBI Shared Information Base, Drawn to Emphasize the Logical View of the Infosphere* 8-15
Figure 8-5. *Taxonomy of the DII COE*........ 8-21
Figure 8-6. *A Top-Level Concept of the JBI as a Collection of Systems and Services Interacting via the Global Information Grid (GIG)*........ 8-24

Figure 4E-1. *Advanced GMTI/SAR Radar Models* ....Appendices 4-12

Figure 6G-1. *DII COE and COE-Based Systems* ....Appendices 6-59

List of Tables

Table 2-1. *AOC Related Publications*........ 2-15
Table 2-2. *Potential Reductions in AOC Manning AOC/AFFOR*........ 2-18
Table 2-3. *CAOC/AOC Manning Proposal*........ 2-19

Table 3-1. *Interoperability Panel Visits*........ 3-4
Table 3-2. *Network Tiers in the U.S. C4ISR Structure*........ 3-19
Table 3-3. *Assessment of Coalition Network Interoperability* 3-19

Table 4-1. *Technology Panel Visits* 4-2
Table 5-1. *Site visits completed by the People and Organization Panel*........ 5-2

Table 5-2. *Assessment of HSI Technologies for Potential* C^2 *Applications* 5-12

Table 6-1. *Annual Cost Estimates of Infrastructure Elements*........ 6-34

Table 7-1. *Tactical Datalinks Managed By The Joint Tactical Datalink Master Plan (JTDLMP)*........ 7-12
Table 7-2. *Common Data Link (CDL) Family Tactical Data Links Not Managed By The JTDLMP*........ 7-13
Table 7-3. *Other Collection Data Links Not Managed By The JTDLMP* 7-13
Table 7-4. *Other Non-Collection Datalinks Not Managed By The JTDLMP* 7-13

Table 4D-1. *Secure Networking*........Appendices 4-5
Table 4D-2. *Detection and Tolerance*........Appendices 4-6
Table 4D-3. *Wrappers* ....Appendices 4-7

Chapter 1
Introduction

1.1 Introduction

This chapter provides the background and context for the Air Force Scientific Advisory Board's (SAB's) study on improving command and control (C^2). Previous studies and actions to enhance the Air Force's C^2 capability over time are reviewed in an effort to advocate the view that substantial change in management and resource allocation is required to fix long-term limitations. The history suggests that, as an institution, the Air Force has not found an effective way to change the system. The value of C^2 is discussed to persuade the reader that greater importance must be accorded C^2 as a weapon system. There has been considerable debate about intelligence, surveillance, and reconnaissance (ISR) as a part of C^2. The study team considers ISR an essential element of operational and tactical C^2. This chapter describes how the Theater Command and Control System fits into the overall C^2 capability. Finally, the chapter advocates the need for the management of combat information to reduce the burden on the warfighter, who is so increasingly overloaded with information that it is difficult to find what is needed.

Volume 1 presented the summary of the study findings and a brief recap of the key recommendations. This volume, Volume 2, provides the detailed reports of the panels, including their charter, approach, and visit and briefing trail. Each panel's chapter provides a more extensive set of recommendations.

1.2 History—"Lessons Learned"

For more than three decades, the Air Force has scrutinized C^2 modernization planning, programs, training, procedures, and architectures and has identified repetitive C^2 problems in each decade. There have been many failed attempts in the 1970s, 1980s, and 1990s to fix these repetitive problems and this SAB Summer Study in 2000 kicks off the fourth decade of analysis in finding the needed fixes.

The redirection of this year's SAB Summer Study topic from limited forward basing to C^2 reflects the Chief of Staff's continuing concern about improving Air Force C^2 capability. Each study made recommendations for fixing the problems the Air Force was having with C^2. Analysis of study recommendations indicates that the same recommendations were made many times, yet the Service is not achieving the vision of Air Force command centers that are linked and have the ability to collaborate globally in support of all commanders in chiefs (CINCs), Services, allies, and the Aerospace Expeditionary Force.

The lessons learned from DESERT STORM and ALLIED FORCE and the results of past Air Force SAB and Defense Science Board studies have determined that U.S. aerospace power capabilities continue to outperform the associated C^2 capabilities. This is particularly evident in theater C^2 of time-critical targeting, battle damage assessment, and campaign assessments.

1.3 C^2 and the Theater Aerospace Command and Control System (TACCS)

TACCS is only one part of the overall joint C^2 capability of the Department of Defense. CINCs of the regional and functional commands each have C^2 systems. TACCS defines the capability

to support a Joint Forces Commander and the Joint Forces Air Component Commander in daily, crisis, or combat operations. TACCS must interface with other component commanders and specifically with Space Command, Special Operations Command, and Transportation Command C^2 systems. This study includes assessment and recommendations for improving all Air Force C^2 capability but focuses on theater C^2 as reflected in the terms of reference.

1.4 The Value of Theater Command and Control

Theater C^2 is defined as the processes and systems that the commander uses to develop the strategy, to plan operations, to control execution, and to assess the effects in crisis or combat. While the well-defined principles of C^2 remain valid, the rapid improvements in combat aircraft and sensor capabilities are driving the need for more rapid decision-making processes. New concepts of operations—including effects-based warfare, precision strike, and flex targeting to attack moving or movable targets—all require integration and synchronization of larger and diverse forces.

Commanders need to optimize force application to rapidly achieve objectives and end the conflict quickly. Enhancing C^2 means reducing the decision cycle time to significantly shorter timelines than the adversary's. This enables the commander to dynamically gain the initiative and respond to opportunities. The key elements of dynamic C^2 are knowledge of the adversary, real-time knowledge of the battlespace, distributed knowledge of the commander's intent, decentralized execution, dynamic control of sensors and shooters, and real-time assessment of effects. C^2 must be improved in order to improve our force effectiveness today and to be prepared to exploit the capabilities of our future forces such as the F-22, the Joint Strike Fighter, the airborne laser, and other systems.

1.5 ISR in Command and Control

Commanders need information and knowledge to make effective decisions in all elements of combat or crisis operations. As the speed of operations accelerates, commanders require more responsive processes for decision-making. Because of their traditional use of ISR to gather information of strategic value, control of those assets has been retained at the very high levels and priority given to collection for Washington decision makers. There is a growing recognition that those assets need to support the Joint Task Force (JTF) Commander. Significant improvements have been implemented and others planned to make these systems more responsive to the dynamics of combat and crisis operations. U.S. Space Command has implemented a number of support concepts to aid the supported CINC and the JTF Commander. Other assets, such as the Joint Surveillance Target Attack Radar System and the Predator and Global Hawk unmanned aerial vehicles, have been designed to give the operational commander dedicated assets to support operations.

Integration of this capability is essential to optimize the commander's knowledge of the battlespace. Sensor management is an integral part of C^2. The only way to speed the planning and execution process is to dynamically manage the ISR assets. Combining ISR and combat aircraft to find and destroy moving or movable targets requires the dynamic execution of both capabilities. Therefore the study concluded that ISR is an essential element of C^2.

1.6 Combat Information Management

Dynamic battle management requires the management of information. *Joint Vision 2010* defines the goal of information dominance. But information dominance implies more than just obtaining information: it means converting that information to a complete understanding of the situation and sharing that understanding with decision makers at every echelon at the right time, in the right format, and at the right level of detail. The amount of information available to commanders today has increased dramatically in both quantity and quality. But possession of large amounts of information does not necessarily enhance C^2. Information overload; lack of interoperability; immaturity in fusion; outdated tactics, techniques, and procedures (TTPs); and the lack of an information operations function all contribute to latency in decision making.

This Study recognizes the need to enhance C^2 by creating an information management capability, including trained staff; TTPs; and support tools to control access and ensure dissemination to authorized users. The SAB studies on C^2 in 1996 and on information management in 1998 and 1999 are recommended for further understanding of this issue.

1.7 Summary

The chapter provides the foundation and context for the remainder of the report. The Air Force's documented difficulty in achieving the needed capability of C^2 as well as the value of C^2 in today's and future operations should stimulate the reader to understand the study's conclusions and recommendations. The importance of ISR and combat information management is also included.

What follows are the reports of the individual panels making up the study team. The reports are organized with the panel's detailed findings and recommendations included in those chapters.

(This Page Intentionally Left Blank)

Chapter 2
Concept and System Definition Panel

2.1 Introduction

The 1996 Air Force Scientific Advisory Board (SAB) Command and Control (C^2) study stated, "Systems are stovepiped from the very beginning in terms of how they are defined, funded, advocated and managed by the Air Force…The stove piping problem extends to the very core of how forces are equipped." An additional theme is reflected in Einstein's words: "The world we created today has problems which cannot be solved by thinking the way we thought when we created them." Achieving the Air Force Chief of Staff's (CSAF's) goal of linking together Air Force C^2 requires that we not only, look back at what the Air Force has already tried in the past, but also follow Einstein's advice and *fundamentally change the way the Air Force thinks about C^2*.

2.2 History "Lessons Observed"

CSAFs have chartered numerous studies and conducted many four star reviews in their attempts to "fix" the Air Force C^2 problem. These CSAF studies began with the 1986 Air Force Studies Board Summer Study, this study was, in turn, followed by 1992 and 1993 Command, Control, Communications, Computers, and Intelligence (C^4I) Broad Area Reviews, 1996 SAB Summer Study, 1997 C^2 Task Force, 1997 C^2 Four-Star Summit, and this 2000 SAB C^2 Summer Study. The CSAFs also established a new Air Staff C^2 Directorate, an Air Staff C^2 General Officer Steering Group, and the Aerospace C^2 Intelligence, Surveillance and Reconnaissance (ISR) Center in their attempts to "fix" C^2.

The redirection of this year's SAB Summer Study from "limited forward basing" to "C^2" reflects the CSAF's continuing frustration with Air Force C^2 capability. Each of the past studies made recommendations for fixing the problems the Air Force was having with C^2. Analysis of study recommendations indicates that the same recommendations were made many times, yet the service is not achieving the vision of Air Force command centers that are linked together and have the capability to collaborate globally in support of all commanders in chiefs (CINCs), services, allies and the Aerospace Expeditionary Force (AEF).

2.3 Commitments and Culture

A thorough review indicates that the recommendations of this study are consistent with those of past studies on Air Force C^2. For 10 years the Air Force has accurately and repeatedly identified its C^2 problems, worked the margins, and not made substantial progress in resolving these persistent problems. The Air Force's fragmented and stovepiped major air command (MAJCOM) views of C^2 are the result of a weak Air Force commitment to the importance of enterprise-wide Air Force C^2 capability. In addition, the Air Force system of education, training and operations does not inculcate current and future leaders with an abiding awareness that C^2 is the foundation upon which all the Air Force core competencies are built. Consequently, Air Force management of its C^2 enterprise, throughout its history, has lacked vision and a constancy of purpose. All the good intentions and actionable recommendations of today will be stacked with those of yesteryear's studies unless senior leadership demands an enterprise-wide view of

C^2 and is committed to building the capability. The leadership must also ensure that this enterprise-wide C^2 capability is trained and operated in peacetime, as it will operate in wartime. Air Force MAJCOMs do not go to war individually, but team together in support of all CINCs, services, allies and the AEF. Therefore an enterprise-wide C^2 system is needed.

2.4 Establishing and Managing the Air Force C^2 Enterprise

2.4.1 Institutionalizing Enterprise-Wide C^2

A clear vision must guide any organizational transformation by motivating and compelling its people. A C^2 vision should be short and simple, capturing C^2 as the core business of the Air Force. It should re-enforce the doctrinal value of centralized planning and decentralized execution, provide a theater perspective, and clarify the command relationships to achieve unity of command. Such a vision of Air Force C^2 exists. It was documented in the Aerospace Command and Control, Intelligence, Surveillance, and Reconnaissance Center's (AC2ISRC's) *USAF C^2 CONOPS, Dynamic Aerospace Command—USAF Command Centers Collaborating Globally in Support of all CINCs, services, allies and the AEF*. It should be embraced by the Air Force leadership and institutionalized. Such a vision, backed by senior leadership's commitment to transformation, will enable the Air Force to embrace a true understanding of C^2 as the life-blood to Global Vigilance, Global Reach, and Global Power. The Air Force also needs to follow the Joint Staff's *Joint Vision 2010* (*JV2010*) lead and elevate C^2 to a prominent role in its vision.

Recommendations

- *Endorse and institutionalize a compelling C^2 vision—the first step to recognizing the essential link between aerospace power and C^2. (CSAF)*
- *Add an enterprise-wide vision of C^2 to the Air Force Vision Statement to ensure that C^2 becomes the foundation for Air Force core competencies (CSAF)*
- *Ensure that this Air Force C^2 vision supports the JV2010 and FV2020 visions*

2.4.2 C^2, The Foundation of the Global Engagement Arch

Figure 2-1. *The Global Engagement Arch*

Effectively accomplishing the Air Force mission depends on how C^2 is performed. As a result, C^2 should be viewed, along with quality people, as the foundation of the Global Engagement Arch. It is the enabler for the effective employment of Aerospace Power. The Key to achieving an elevated role for C^2 and the vision of "command centers collaborating globally" is to establish an empowered single manager for C^2 at Air Force level.

Recommendations

Establish a single manager for C2 at Air Force level. (CSAF)

Individual should

- *Be an Air Force Council member*
- *Have C2 operational experience*
- *Be empowered to propose solutions to cross-program and MAJCOM issues*
- *Be the Air Force Chief Information Officer (CIO) and represent the Air Force at the Department of Defense (DoD) CIO Panel*
- *Have assigned directors, to include C2, Communications, ISR, and Agile Combat Support and have appropriate liaisons/DRUs*
- *Hire skilled Information Technology experts and C2 professionals for key positions. IPAs should be considered for these positions.*
- *Be responsible for publishing a single Air Force C2ISR Strategic Plan that provides comprehensive Air Force direction for C2 operations, modernization and sustainment*
- *Define and sponsor a unifying infrastructure approach to system development*

2.4.3 The Air Force C^2 System and Enterprise-wide C^2 Management

The lack of understanding of the Air Force C^2 vision and constancy of purpose is evident at many levels. Examples are: the excessive number of Program Element (PE) Codes spread across too many panels in the Air Force Corporate Process; too many offices in charge of different parts of the same C^2 system, no central Global Command and Control System (GCCS) management structure aligned with Joint Staff instructions; confusing placement of AC2ISRC under a MAJCOM while it holds Air Force–level responsibilities, and so on. This lack of coherent, focused management at the Air Force leadership level has fostered stove piped C^2 systems, multiple disparate improvement efforts striving for similar outcomes, confused training requirements, inadequate manning, and difficulty in deciding on a baseline C^2 structure.

The Air Force also needs to view its C^2 system as an integrated system of weapon systems that is composed of many C^2 centers or nodes. Each is managed as a "weapon system" and has a Designed Operational Capability Statement, operational qualifications, currency requirements, and inspection programs. In addition, the Air Force should manage these C^2 weapon systems with the same job performance and safety standards as it does other weapon systems that have life-and-death operational consequences. *The goal of a C^2 improvement program should be a distributed and collaborative system of systems operated by certified C^2 warriors.* Additionally, an effective C^2 capability requires an effective Common Operational Picture (COP) that not only correlates data, but also fuses information into knowledge for the decision maker. The COP's role in Air Force C^2 is crucial because it will dictate the nature of information management at all theater levels, from the weapons system displays to the theater CINC or Joint Task Force Commander's operational picture.

The following recommendations are the result of applying an Air Force enterprise-wide view of C^2 to the Air Force Planning, Programming, and Budgeting System; the Requirements System, the Acquisition System and C^4I Support plans. There are six fundamental components of the enterprise-wide C^2 weapons system: (1) individual command centers and nodes, (2) C^4I software applications, (3) C^4I software infrastructure, (4) communications infrastructure (5) the information infrastructure and (6) Air Force sensor programs.

Following is a detailed description of the six major components of the C^2 weapons system:

1. *Individual C^2 Command Centers and Nodes*: The foundation of this Air Force enterprise-wide view is C^2 centers and nodes that are managed as an integrated weapons system consisting of people, processes, and technology. These C^2 Centers are operated by many MAJCOMs and *must be* manned by highly trained and certified C^2 warriors. The C^2 warriors are not only highly skilled, for example, in the combat, mobility, space, and special operations missions but also in the art and science of the application of aerospace power in joint and combined operations. Fundamental to the success of the proposed Air Force C^2 weapon system concept is an enterprise-wide vision of a globally collaborating partnership of Air Force C^2 centers and nodes. These C^2 centers and nodes bring to the CINCs a multi-MAJCOM C^2 capability that is far greater than the sum of its parts. Each weapon system node is funded by a program element that funds manpower, communications and computer equipment, facilities, and sustainment. All program elements should be assigned to a single C^4I panel in the Air Force Corporate Process. Each node has a concept of operations (CONOPS) and a set of training publications—such as Air Force Instructions (AFIs) and

tactics, training, and procedures (TTPs)—that describes its responsibilities within the enterprise-wide C^2 system and how it functions in the multi-Service and joint enterprise-wide C^2 system. Each node should also have a C^4I Support Plan that describes its configuration control process and how it will be sustained. Finally, weapon system nodes should have a supporting System Program Office and an Acquisition Program Management Decision. The CONOPS, Operational Requirements Documents (ORDs), PEs, Program Management Directives (PMDs), Program Managers (PMs), C^4I Support Plans (C^4ISPs) and Mission Area Plans (MAPs) need to be redrafted and/or reorganized so that they all align by weapon system node. For example the air operations center (AOC) (and all other nodes in the system of weapon systems) needs it's own CONOPS, ORD, PE, PMD, PM, C^4ISP, etc. Aligning these documents and entities by node is key to achieving the Air Force C^2 vision of "command centers collaborating globally." The system of weapon systems should be described and defined in one overarching CONOPS, one Strategic Plan, one Capstone Requirements document, etc. A single integrating PMD should also be written to direct the various MAJCOMs and agencies to take the actions necessary to achieve the Air Force C^2 vision. Well-defined actions should be spelled out in this integrating PMD. See Appendix 2D for a matrix table depicting the above concept.

2. *C^4I Applications*: C^4I applications are the software information-processing and decision tools of the C^2 Weapons System. Not every C^2 center may use the same C^4I applications. Some applications will be common across all C^2 centers; however, other applications will provide specialized capability. For example, Air Mobility Command (AMC) or Space Command may use applications that Combat Air Forces do not use, such as AMC's C^2 Information Processing System or Space Command's Space Battle Management System.

3. *Software Infrastructure*: The software infrastructure should be the common software foundation that supports all C^2 weapons systems nodes. It is common across all MAJCOMs, CINCs, and Services. All C^4I applications and software infrastructure development efforts should be consolidated under two programs: the Global Command and Control System-Air Force (GCCS-AF) and GCCS-AF Real Time Weapons Control. The requirements for these two programs should be identified in a single ORD for each program and each program must have a single PE, PMD, MAP, and C^4ISP. Both programs should be consolidated on a single C^4I panel within the Air Force corporate process. Information systems that support agile combat support tracking and decision-making should be developed under the GCCS-AF program.

4. *Communications Infrastructure*: The supporting communications infrastructure is divided into four areas: (1) tactical communications, (2) base-level communications, (3) long-haul communications, and (4) satellite communications. Requirements for the communications infrastructure should be identified in a single ORD, and funding provided in a single PE for each of the four areas. All four programs should be consolidated on a single C^4I panel within the Air Force corporate process and have a single MAP and C^4ISP.

5. *Information Infrastructure*: The information infrastructure consists of three parts: (1) common information management, (2) datalinks, and (3) Joint Interoperability Tactical Command and Control Systems message sets. All three areas should be consolidated under a single GCCS-AF Integration Program and have a single CONOPS, ORD, PMD, MAP, and

C^4ISP. All three programs should be consolidated under a single C^4I panel in the Air Force's Corporate Process.

6. *Air Force Sensor Programs*: The platforms associated with these programs are outside the C^2 Weapons System; however, they are the eyes and ears of C^4I, and the information they provide is a fundamental part of the C^2 weapons system.

The above proposal would greatly simplify what are now complex and fragmented C^2 programs into fewer logical and well-defined and -understood components of the C^2 weapons system.

Recommendations

Formalize the definition of the C^2 system of C^2 weapon systems and nodes

- *Develop and align an overarching family of C^2 CONOPS (AF/XO)*
- *Develop and align C^4ISPs to the C^2 Weapon Systems and nodes (AF/SC)*
- *Develop a capstone PMD with subordinate PMDs and System Program Offices that are aligned with the family of C^2 CONOPS (AF/XO)*
- *Merge the C&I Support Plan and the C^2ISR Campaign Plan into a single Air Force C^2 Strategic Plan (Air Force CIO)*
- *Restructure programs and PEs by using the C^2 System of Weapons System and nodes and links concept (AF/XP)*
- *Designate the individual C^2 centers and nodes as weapon systems and inspect, train, and operate them as such (AF/XO)*

Create and fund a C^2 integration program

- *Establish a C^2 Integration Program Office that is empowered to direct and coordinate all interoperability development between C^2 centers and nodes (SAF/AQ and AF/XO)*
- *Create and maintain a capabilities-based C^2 Weapons System Roadmap and review it regularly (AF/XO)*
- *Create and maintain a cross-program C^2 Weapon Systems Integration Roadmap to monitor progress and for review by the CSAF and the Secretary of the Air Force (SAF) annually at the C^2 capabilities-based Quarterly Acquisition Program Review (SAF/AQ and AF/XO)*
- *Develop a long-term strategy for cultivating the Joint Battlespace InfoSphere (JBI) and fund it (AF/XP and AF/XO)*
- *Establish the Integration Task Force as per AFI 63-123 (AF/XO)*

2.5 Expeditionary Air Force C^2 Baseline

The Expeditionary Air Force C^2 system of systems is a subset of the Air Force C^2 enterprise-wide C^2 system and is composed of the continental United States (CONUS) based command and intelligence centers and of the Theater Air Control System with its supporting airlift C^2 capability. The various nodes are operated by numerous MAJCOMs and agencies. Therefore, overall management and integration of this system of systems that will "collaborate globally in support of the CINCs" must be accomplished at the Secretariat and Air Staff levels of the Air Force.

2.5.1 Expeditionary Aerospace C^2 System Components

This section describes the existing C^2 centers (see Figure 2-2) that support a commander's capability to plan, direct, coordinate, and control forces to accomplish assigned missions.

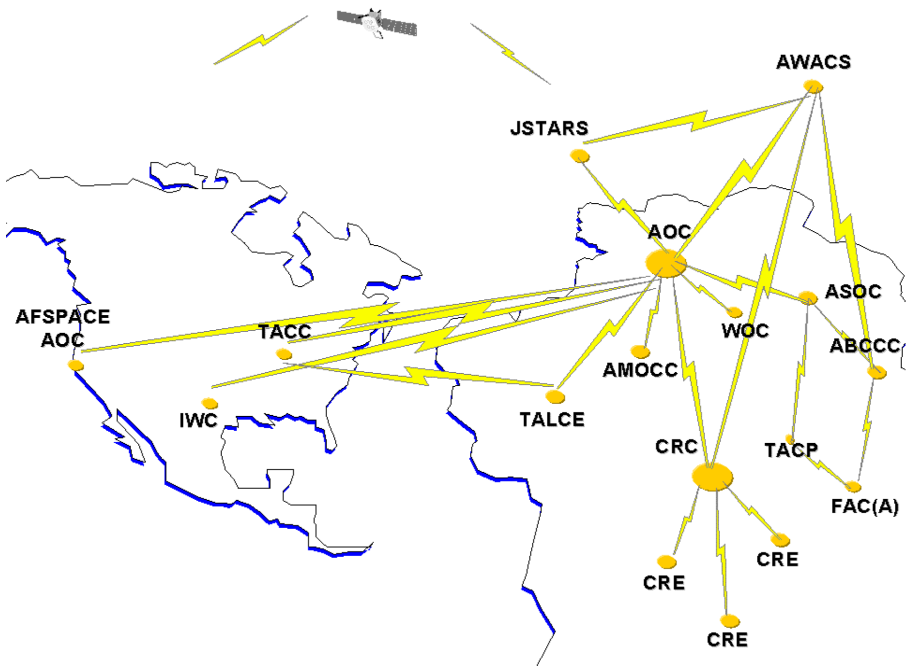


Figure 2-2. *Expeditionary Aerospace C^2 System Centers*

2.5.2 The Theater Air Control System

Air Force forces (AFFOR) respond to worldwide missions in support of theater CINC missions that require deployment of Air Force C^2 capability. At the operational level of warfare, C^2 weapons systems provide Air Force C^2 in support of the Aerospace Expeditionary Task Force Commander, Commander, Air Force Forces (COMAFFOR), and the Joint/Combined Force Air Component Commander (J/CFACC).

Air Force Forces Headquarters (HQ): The mission of the AFFOR HQ is to plan, monitor, execute, and assess Air Force operations and sustainment in support of COMAFFOR. It is functionally separate from the AOC's air operations planning and execution activities; however, AFFOR activities fundamentally affect the air campaign by both enabling and constraining air operations. The AFFOR HQ is COMAFFOR's C^2 element. COMAFFOR C^2 has two facets: operational and service. The operational commander handles technical, administrative, and tactical matters. The service element manages the "beds, beans, and bullets" issues.

Combined Aerospace Operations Center (CAOC): The overarching mission of the CAOC is to employ decisive joint and coalition aerospace power through effective C^2 in support of aligned commands and CINCs worldwide. The CAOC is the operational C^2 center in which the CFACC has centralized the functions of planning, direction, and control over aerospace resources. The CAOC performs duties in support of the C/JFACC, the Airspace Control Authority and the Area Air Defense Commander. The CAOC produces, distributes, and executes the integrated air

tasking order (ATO). Individuals representing joint, coalition and/or allied forces assist in the operation of the CAOC.

Control and Reporting Center (CRC): The CRC is directly subordinate to the CAOC and is a primary control node concerned with decentralized execution of air operations. The CRC directs region or sector air defense and provides aircraft control and monitoring for both offensive and defensive missions. The CRC also may establish liaison with allies or components to exchange airspace management and air defense data from related control systems.

Control and Reporting Element (CRE): The CRE is subordinate to the CRC and augments the CRC's mission by extending radar surveillance and airspace control capabilities within the area of responsibility.

Air Support Operations Center (ASOC): The ASOC is directly subordinate to the AOC and is the primary liaison element to the corps headquarters for air support. It is primarily concerned with the exchange of combat information between air and ground units for immediate air support of ground operations. It plans, coordinates, and directs tactical air support of ground forces, normally at corps level or below. The ASOC is delegated execution authority to provide fast reaction to requests for offensive air support such as close air support (CAS) or air interdiction.

Tactical Air Control Party (TACP): The TACP is subordinate to ASOC and responsible for controlling close air support and advising and assisting the U.S. Army commander when air support is required.

Wing Operations Center (WOC): The WOC, both fixed and deployed, includes the following functional areas: operations control, maintenance coordination, reports, training, and battle management and survival recovery. MAJCOMs, in coordination with assigned or supported CINCs, may specify additional functions for collocation or removal from the WOC.

Tanker Airlift Control Element (TALCE): The TALCE coordinates and executes both preplanned and immediate airlift requirements with Tanker Airlift Control Center (TACC) and the Air Mobility Division (AMD) within the AOC. The TALCE reports to the Air Mobility Element within the AMD of the CAOC. TALCE cadre members are responsible for conducting airfield assessments worldwide. TALCEs are provisional, deployed organizations composed of various mission support elements, established at fixed, deployed, and en route locations where operational support is non-existent or insufficient.

2.5.3 Theater Airborne C^2 Assets

Airborne Warning and Control System (AWACS): AWACS performs missions designed to extend radar coverage, enhance link operations, assist in track identification, and gather intelligence data. AWACS provides all-weather, all-terrain target detection, weapons control, and threat warning. AWACS provides area surveillance and control when ground radars are not in place, augments operational radars, supports air operations conducted in support of ground forces, and provides surveillance, early warning of hostile aircraft, control of fighter aircraft, airspace management, and ADA coordination functions during contingency operations.

Airborne Battlefield Command and Control Center (ABCCC): The ABCCC operates as part of the Airborne Elements of the Theater Air Control System. Its primary function is to provide management of tactical air forces and to liaison with ground forces. Its general employment role

is an extension of AOC combat operations and as an alternate ASOC/Direct Air Support Center. However, an integrated battle management and communications system onboard the EC-130E aircraft enables the battle staff to provide air and ground component commanders with a flexible airborne C^2 capability.

Joint Surveillance Target Attack Radar System (JointSTARS): JointSTARS provides dedicated support to ground commanders for planning and execution of the land battle and theater air interdiction campaign. JointSTARS is a theater-wide battle management C^2 platform that conducts ground surveillance to develop an understanding of the enemy situation. JointSTARS also provides attack support functions to friendly offensive air elements.

A-10 Forward Area Controller (FAC-A): TACP operating from a suitable aircraft, the FAC-A coordinates air strikes between the TACP and CAS aircraft. The FAC-A provides terminal control, relays CAS reports, provides immediate target and threat reconnaissance, and marks targets for the attacking aircraft. The FAC-A can perform tactical battle management by cycling the CAS flights through the target area, while prioritizing the targets in coordination with the friendly ground force.

2.5.4 Supporting CONUS Command Centers

The following Air Force Commander in Chief, U.S. Space Command (USCINCSPACE) and U.S. Transportation Command centers provide critical support for successful Expeditionary Aerospace Force's (EAF's) operations in support of the CINC.

Air Force Space Command (AFSPACE) AOC: The AFSPACE AOC facilitates the integration of information and resources, implements and coordinates the Commander, AFSPACE (COMAFSPACE) tasking and priorities, makes recommendations to superiors, and validates and prioritizes requests for USCINCSPACE. The 14AF AFSPACE AOC is an in-place equivalent of the theater AOC and accomplishes parallel planning and operational functions for COMAFSPACE

Tanker Airlift Control Center (TACC): The TACC, Headquarters AMC, located at Scott Air Force Base (AFB), IL, is the command's hub for planning, scheduling, tasking, and executing America's mobility forces around the world. The TACC is dedicated to providing quality service to a wide range of mobility customers. In effect, the TACC is "one-stop shopping," which brings requirements and capabilities together to accomplish AMC's Global Reach mission efficiently and effectively.

Air Force Information Warfare Center (IWC): The Air Force Information Warfare Center at Kelly AFB, TX, engages in a myriad of activities supporting its role as the Air Force Information Warfare executive agent. Its mission is to develop, maintain, and deploy information warfare and C^2 warfare capabilities in support of operations, campaign planning, acquisition, and testing.

2.5.5 Operational and Systems Architecture Development Factors

Each of the above centers is responsible for a variety of C^2 functions which are supported by a "business process" that is defined in an operational architecture and information technology systems and by communications that are defined by a systems architecture. This section offers an analysis of operational and systems architecture development factors.

The C^2 system is a system of systems (as shown in Figure 2-3). The large majority of individual elements that make up the overall C^2 system are contributed by non- C^2 organizations. In fact, the unique functions of the C^2 system are planning and execution control.

Elements of each C^2 System are unique to the theater or crisis. These include the specific allocated ISR assets, weapon delivery platforms, communications, combat support, and information management systems.

Additional assets may be available on a shared basis to the commander and augment the organic systems—specifically, strategic ISR and information management systems, long-range weapon delivery platforms such as B-2s, long-haul communications, and logistics and combat support systems.

The interactions between these systems in a C^2 context are dominated by information exchanges, principally in the form of tasking, collected sensor data, and system status and capability reporting.

The nature of systems of systems is that the user does not have the option to specify the nature of the interfaces between the component systems. It is thus incumbent on the system architects and acquisition organizations to assure that, to the extent possible, operational systems conform to interface standards that enable the user to configure a system of systems that meets the needs of the particular situation. The set of interfaces that are appropriate include those implemented by the systems of the other Services and U.S. allies.

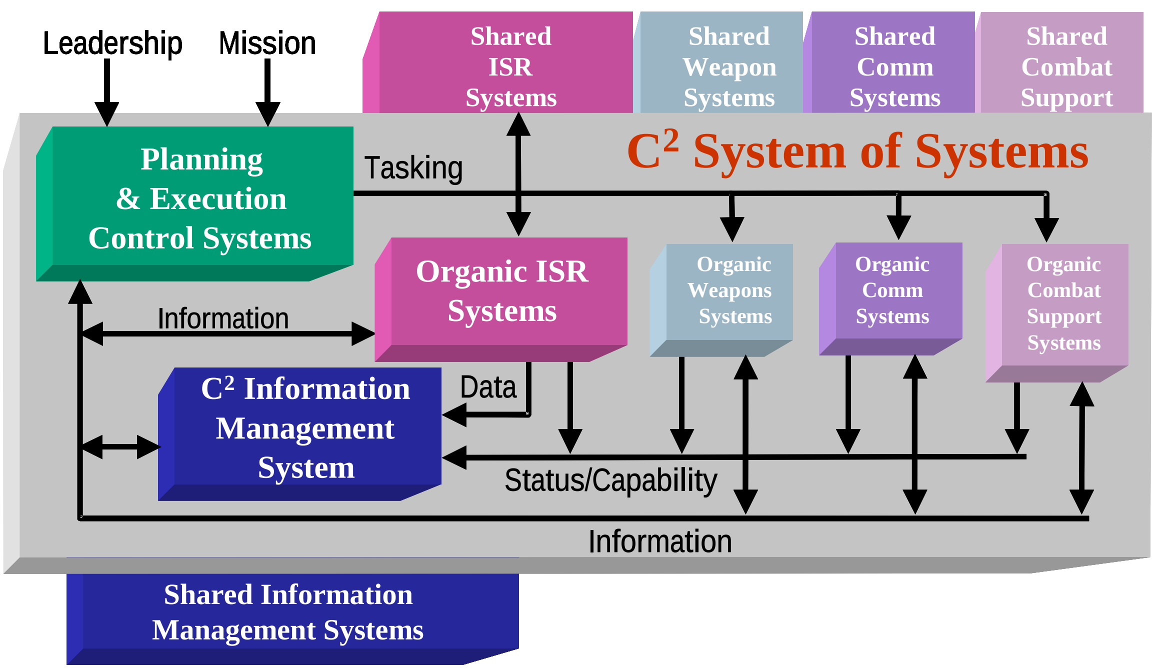


Figure 2-3. *Existing C^2 System Architecture*

The component functions that make up the Planning and Execution Control Process (see Figure 2-4) include assessment, strategy decision, planning and resource allocation, and dynamic execution. Assessment includes the analysis of ISR data and the characterization of the current

situation. Strategy decisions set the objectives of the campaign and describe the desired effects to be achieved by aerospace power. The planning process leads to allocation of available resources as reflected in taskings levied on organic weapon systems, ISR assets, communications resources, and combat support organizations. Some taskings are requests for resources held at a higher level that may or may not be granted. To the extent that these requests for shared resources are not satisfied, the associated plans will have to be adjusted or alternative courses of action initiated to accommodate the deficiency.

Once the plan begins execution, adaptation and adjustment will be necessary to fix evolving problems and maintain the initiative.

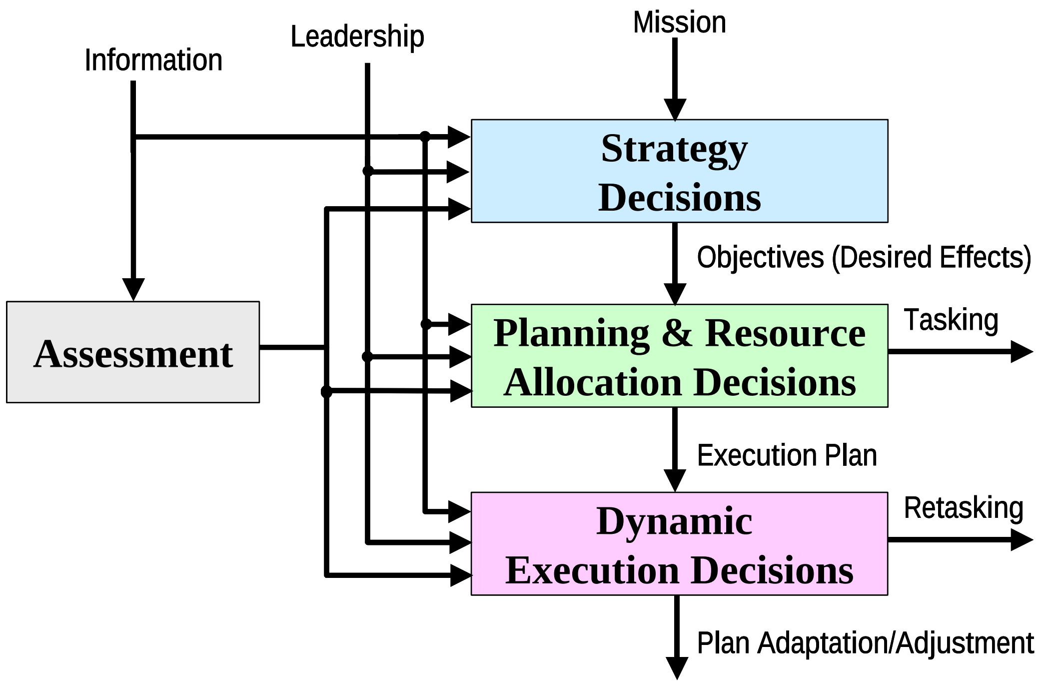


Figure 2-4. *Planning and Execution Management*

The planning and resource allocation process in an AOC is responsive to the individual mission areas and functions that staff the AOC. These include air interdiction, airlift, close air support, combat search and rescue, communications, defensive counter-air, information operations, intelligence analysis, ISR collection management, logistics, offensive counter-air, special operations strike, suppression of enemy air defenses, and tanker support.

The above sections of this report started with a concept of an Air Force enterprise-wide view of C^2 that could be used to pull together and link C^2 within the Air Force. We also added more “meat on the bones” on managing C^2 as a weapons system and proposed a concept for the Expeditionary Aerospace C^2 System. The Expeditionary Aerospace C^2 System comprises globally linked command centers and nodes with C^2-assigned forces and is trained and equipped to collaborate in support of the theater CINCs and Joint Force Commanders (JFCs). This next section focuses on the theater subset of the Expeditionary Aerospace C^2 System.

2.6 Building the Future—The Theater Aerospace Command and Control System (TACCS)

2.6.1 Combined Aerospace Operations Center

The possibility that an Air Force–provided AOC will operate in war as a "U.S.–only" command center is highly remote. Theater air operations will be combined operations. As a result, the design of the AOC weapons system must deal with the security issues associated with multinational air operations. The SAB believes that these requirements not adequately addressed in the AOC Weapons System requirements and are not adequately addressed in its system architecture design.

This section presents significant issues that will affect a commander's ability to plan and execute an air campaign. The SAB proposes the following approaches to improve Air Force CAOC organization, training, and equipage.

2.6.2 CAOC/AOC Organization

The organization of the Theater Air Control System is well defined and documented, with the exception of the CAOC/AOC. Air Force AOCs support a wide variety of CINCs throughout the world. The fact that these Air Force AOCs support a wide variety of commands often results in extensive customization. Other Air Force weapon systems are not customized for each theater of operations. CAOC/AOC should follow the "organize, train, and equip" concept the Air Force uses for other major weapon systems, such as the F-15, F-16, and AWACS. These are not customized by theater, but provided by the Service to the theater as a combat capability package.

The CAOC is the operational C^2 center in which the CFACC has centralized the functions of planning, directing, and controlling aerospace resources. The probability that the Air Force will operate a "U.S. only" AOC is extremely remote, yet many of our development efforts do not address the underlying coalition security and system engineering issues in the technical design of the AOC systems infrastructure. Coalition operations must be viewed as the operational baseline of the CAOC/AOC Weapon System and, as a result, become the driving force behind its organization, technical design, and systems engineering. The following is a description of its basic organizational structure.

CAOC Divisions: The CAOC/AOC has five core divisions.

Strategy Division: The Strategy Division develops, refines, disseminates, and assesses the progress of the JFACC's aerospace campaign strategy.

Combat Plans Division: The Combat Plans Division is responsible for Joint Aerospace Operations Center (JAOC) near-term aerospace operations planning. It refines, disseminates, and assesses the progress of the JFACC aerospace strategy. It also prepares and refines two ATOs beyond the executing ATO.

Combat Operations Division: The Combat Operations Division executes the ATO. It analyzes, prioritizes, and, if necessary, recommends redirection of assets to the JFACC. It also coordinates emergency air support requests.

Intelligence, Surveillance, and Reconnaissance Division: The ISR Division provides integrated distribution of ISR information and processes. It also develops, plans, and coordinates all aspects of ISR capabilities for the planning, execution, and assessment responsibilities of the CAOC/AOC.

Air Mobility Division: The Air Mobility Division plans, coordinates, tasks, and executes intratheater and intertheater air mobility forces. It coordinates aerial refueling plans, tasks, and schedules. The Air Mobility Division ensures that air mobility missions are visible in the AMC standard C^2 system and reflected in the ATO/Airspace Control Order.

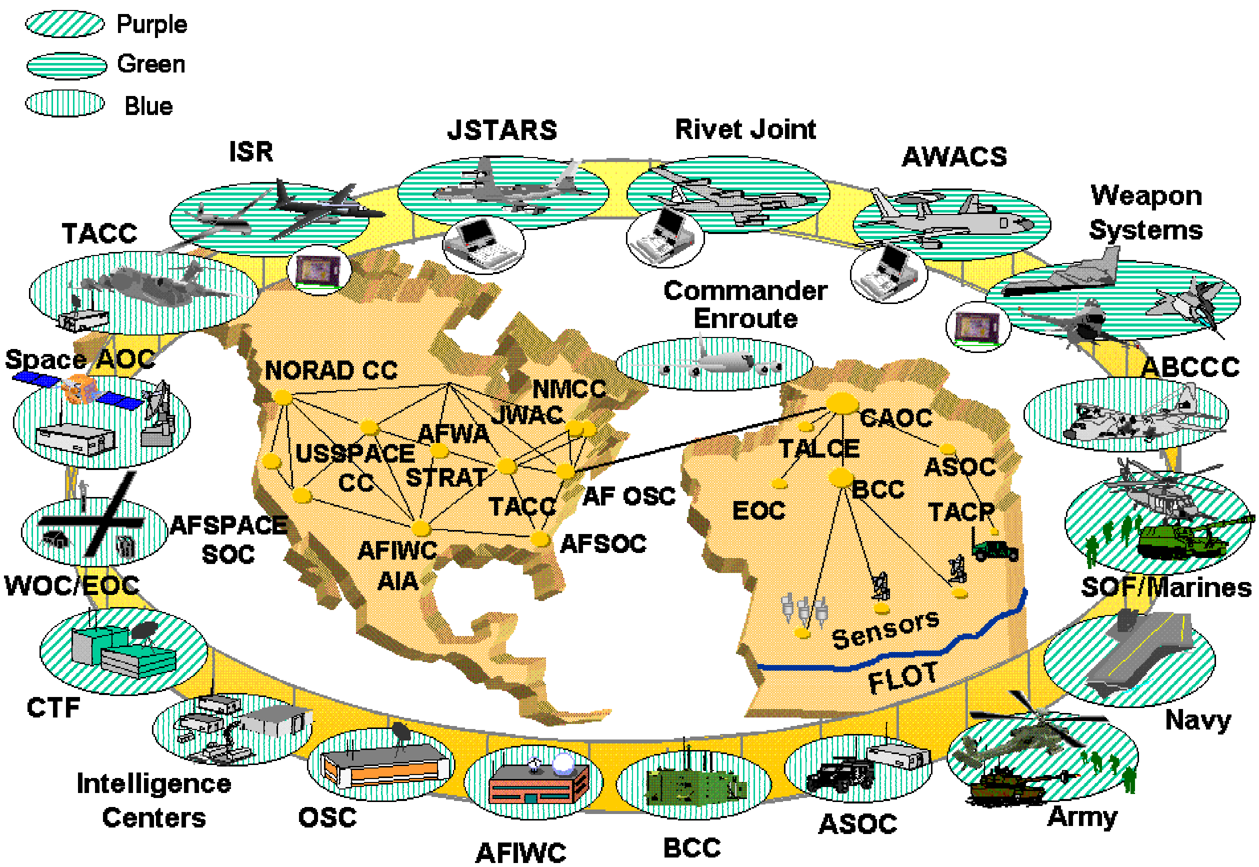


Figure 2-5. *CAOC/AOC C^2 System Operational Relationship*

CAOC/AOC Combat Operations Staff: An AOC is led by an AOC Director, has five divisions, and multiple support teams. As an example, the following are brief descriptions of principal positions in a combat operations division.

CAOC/AOC Director: The AOC Director is responsible for the centralized planning, directing, controlling, and coordination of air effort and all JFACC assets. Responsibilities of the Director include supervising the five AOC divisions and approving, as well as releasing for publication, the ATO. The AOC Director also monitors, evaluates, and adjusts as necessary to meet changing tactical situations while executing the ATO. The AOC Director advises the commander of problems or factors affecting achievement of assigned objectives.

Director of Combat Operations (DCO): The DCO works for the AOC Director and is in charge of 24-hour operations in the Combat Operations Division (COD). The COD is responsible for the current ATO during execution and for making necessary changes to affect the theater air operations.

Chief, Combat Operations (CCO): The CCO reports directly to the DCO and has overall responsibility for the direction and supervision of the COD. The CCO ensures that current operations correspond to JFC/JFACC/AFFOR directives and is responsible for maintaining viable air and missile warning as well as defense operations. At the discretion of the AOC Director, the CCO may be the senior officer within the COD.

Senior Offensive Duty Officer (SODO): The SODO's main role is to monitor ATO execution and make recommendations to the CCO. The SODO exercises authority over offensive and support operations. The SODO supervises the individual mission cells and weapon system experts who augment those positions. The SODO's main role is to monitor ATO execution, recommend changes to the ATO, and manage mission and strike package retasking as directed by the CCO.

Fighter Duty Officer: The job of Combat Operations duty officers is to be the expert in their assigned aircraft and/or mission specialties. They represent the concerns of their deployed and employed units and act as a conduit for information between their units and the AOC leadership.

The SAB suggests reorganizing the CAOC using the joint staff structure. This results in a widely understood CAOC organization that is fully compatible with all other Services' and CINCs' organizational structures.

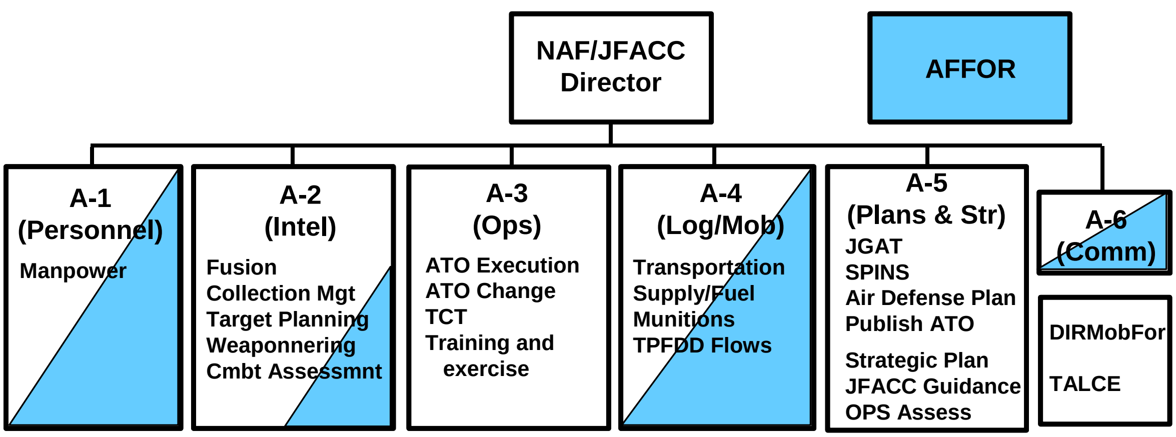


Figure 2-6. *Proposed AOC Joint Organizational Structures*

Recommendations

Build CAOCs—not AOCs. Deal with the security and weapons system design challenges up front (AF/XO)

Reorganize the CAOC using the joint organizational model (AF/XO)

2.6.3 AOC Process Issues

While the fundamental mission of every CAOC/AOC is similar, each theater performs CAOC functions differently. Historically, there has been little effort to standardize CAOC operations. The North Atlantic Treaty Organization Allied Tactical Air Forces (ATAFs) each planned and executed their air campaigns using different procedures and equipment. For example, CONUS augmentees to the 2ATAF CAOC in northern Germany, known as the Allied Tactical Operations Center, would find very different procedures and processes from those found in the CAOCs supporting 4ATAF (southern Germany), 7AF (Korea) and the CONUS-based numbered air forces (8AF, 9AF, and 12AF).

It seems clear that the Air Force needs to implement a CAOC "baseline" that provides a significant level of standardization while providing some flexibility for unique theater operational needs. Standardized CAOC processes would allow a far more efficient cross-flow of trained people, provide rapid absorption of augmentation personnel, and set the framework for other management actions to further improve the overall conduct of Air Force C^2. A standardized CAOC would also improve the worldwide applicability of the CAOC training provided by the C^2 Training and Innovation Group (C^2TIG) at Hurlburt Field.

The C^2TIG has led the development of a detailed hierarchy of publications for use by fielded CAOCs and training organizations. However, the majority of these documents remain in draft form.

Table 2-1. *AOC Related Publications*

Title	***Date***	***Status***
Air Force C^2 CONOPS	24 Mar 1999	Signed
Enroute Operations Center (EOC) CONOPS	30 Jun 2000	Draft
Space Operations Center CONOPS	15 Mar1999	Signed
C^2 ISR CONOPS	24 Jul 2000	Draft
Battle Control System CONOPS	4 Nov 1999	Draft
Time-Critical Targeting (TCT) CONOPS	8 July 1997	Signed
Air Force AOC CONOPS	19 Apr 2000	Draft
AFI 13-1 Vol. I (AOC Training)	16 Jan 1997	Draft
AFI 13-1 Vol. III (AOC Operations Procedures)	6 Mar 2000	Draft
EAF C^2 Reference Book	27 Jan 2000	Approved for use
AOC Process Manual	1 July 2000	Draft
Blue Order of Battle CONOPS	12 Aug 2000	Draft

The SAB supports the work being done by the C^2TIG at Hurlburt Field. A multi-command AOC baseline group exists, draft AOC baseline publications have been written and it appears that the Air Force is moving toward a standardized CAOC/AOC organization. These efforts have also been sensitive to retaining limited flexibility for theater-specific uniqueness. In addition, the AC2ISRC and the C^2TIG have produced significant numbers of CONOPS, AFIs, and TTP manuals. It was the opinion of the SAB that sufficient CONOPS exist to guide development of the CAOC; however, more work is needed in many areas on training publications. While the

CAOC/AOC baseline project is not a full solution for CAOC standardization, it does set the stage for the follow-on, detailed work required to standardize all Air Force CAOCs.

2.6.4 Improve Theater C^2 Training

The Air Force proudly points to its core competencies because of their uniqueness to the Air Force and the superior way in which they are accomplished. Highly effective training is the main reason for the Air Force's superior execution of its core competencies. Such is not the case with Air Force theater C^2 operations from the unit level to the JFACC. The Air Force does not provide the same quality of training for theater C^2 as for its core competencies. Improving the quality of theater C^2 training will provide an exponential improvement in aerospace operations efficiency and capability.

Growing C^2 warriors and leaders who understand the art and science of the application of aerospace power is the foundation for eliminating the pick-up team process now used to support a wartime contingency. Realistic daily C^2 training, high-quality people, and connected C^2 systems will significantly improve theater C^2 capabilities.

Achieving this objective will require theater C^2 training that is integrated with the peacetime flying training and is done routinely during the 5-day workweek. Integrating AOC training with other theater control centers and real-world flying training will improve the quality of theater C^2 training and standardization. Today's theater C^2 system also needs to have an effective certification process for AOC operators and inspections to ensure compliance with AFIs. Establishing realistic and regular training, standardization and inspection will greatly improve the Expeditionary Air Force's ability to make a smooth transition from peacetime to wartime operations.

Recommendations

Establish a career track for C^2 warriors (AF/XO and AF/DP)

Improve JFACC and CAOC training from the Numbered Air Force down to the wings and air control centers (AF/XO and AF/DP)

Improve cross-MAJCOM C^2 training for support of the EAF (AF/XO and AF/DP

Improve Joint and coalition C^2 training (AF/XO and AF/DP)

2.6.5 CAOC/AOC Training Issues

Air Force CAOC/AOC training programs have lagged in definition and rigor when compared to other weapons systems. This results in a pick-up team approach for CAOC operations in both exercises and in real-world contingencies—a major operational problem.

A brief review of the history of formal CAOC/AOC training may help frame the overall issue as it exists today. The Air Force created the Blue Flag program in the late 1970s with the objective of providing AOC training. The initial goal was to train potential AOC augmentees in theater-specific processes and procedures. Typically, Blue Flag would plan an exercise such as Korea by visiting the theater well in advance of the exercise date. The visit focused on identifying current theater procedures, updating the Blue Flag library with the theater documents, and identifying selected theater personnel to come to the exercise and act as advisors. The Blue Flag AOC was

configured to replicate the theater-specific facility. This approach provided a reasonably high degree of fidelity with regard to each theater's AOC processes. In the late 1980s, both 9AF and 12AF began using Blue Flag as a training vehicle and helped develop the warfighting scenarios. The numbered air force (NAF) staffs relocated to Hurlburt once a year for Blue Flag training which was focused and received very high marks from Gen Horner after his Desert Storm experience.

While Blue Flag continues to provide valuable training, there is no effective mechanism to identify, train and track people who have been trained in theater-specific processes and procedures for CAOC operations.

A second issue is the manner in which CAOC/AOC training is conducted. The requirements for AOC training are defined in AFI 13-1, Vol. 3. This document provides a well-recognized training construct of initial qualification training, mission qualification training (MQT), and continuation training (CT); however, continuity of this construct falls apart during implementation. The MQT program is implemented as a local unit-training program and may not provide the trainee a realistic picture of the dynamic CAOC environment. CT is also conducted at the unit level with occasional opportunities to work in a CAOC exercise, such as a Blue Flag, Ulchi Focus Lens, or similar Joint-level exercises. The SAB concluded that current training falls far short of what is needed and that training is not consistent with the Air Force's belief that we must "train the way we fight." The CAOC Weapons System is complex and needs to be "flown" regularly—not once or twice a year. Theater Battle Management Core System (TBMCS), the primary software system for the CAOC, is extremely capable, but complex. No one individual understands its full capability. Just as Air Force operators must fly complex aircraft frequently and regularly to maintain proficiency, C^2 warriors must operate the complex CAOC weapon system frequently and regularly to maintain proficiency.

Recommendations

Initiate an effective and reliable system to track CAOC-trained personnel (AF/DP)

Identify specific CAOC-trained personnel to fill in as augmentees for unmanned CAOC "spaces" during contingencies (AF/XO)

Task frequent 12/5 CAOC operations for Continuation Training (AF/XO)

Evaluate the effectiveness, style, and size of CAOC training programs-explore distance learning (AF/XO)

Manage the CAOC as a Weapon System (AF/XO)

- *Train CAOC personnel "the way we fight"*
- *Develop a Designed Operational Capability Statement*
- *Establish standards of performance and an effective training, standardization evaluation, and inspection program*
- *Conduct joint training—both live and virtual*
- *Conduct Operational Readiness Inspections*

2.6.6 CAOC/AOC Manning Issues

Air Force–provided AOCs are not fully manned, and there is no reason to expect this situation to improve. The problem is further exacerbated by the lack of C^2 Warrior School slots and the limited number of Blue Flag training opportunities. This lack of quality training opportunities keeps AOC operational proficiency low. The Air Force also has not operationally tested and validated its AOC Unit Manning Documents.

The number of people required for the AOC Quick Response Package (QRP), Limited Response Package (LRP), and Theater Response Package (TRP) has never been operationally tested and verified. However, the Air Force has recently proposed a new Unit Type Code (UTC) composition for the QRP, but the package has not, at this time, been operationally tested and verified. Table 2-2 analyzes potential AOC manning reductions based on the fielding of operationally significant new technology (TBMCS) and implementation of an effective AOC training program.

Table 2-2. Potential Reductions in AOC Manning
AOC/AFFOR

Sorties/day	***Size***	***Today***	***2001***	***2005***
300–900	QRP	441	350	250
900–1,800	LRP	870	600	400–500
1,800–3,000	TRP	1,055/146	800/99	600–700/80

(Note: QRP and LRP do not include AFOR manning)

The SAB also believes that the number of Air Force AOCs must be reduced in order to fix the AOC manning and training problem. Today AOC-assigned manpower is about 30 percent less than authorized, a situation that is not expected to improve in the near term. Furthermore, there are not enough school slots available at the Hurlburt C^2 Warrior School to sustain the AOC crew force, and Blue Flag training opportunities for the AOC Weapon System are limited. The current manning situation, together with the lack of quality training opportunities, severely impacts AOC operational readiness. Therefore, to improve AOC readiness, the board recommends a reduction in the total number of Air Force AOCs to five and the realignment of existing manpower as shown in Table 2-3. This reduction in AOCs will allow the remaining AOCs to be fully manned and fix the 30 percent less than authorized situation of the NAFs today. The Combat Air Forces NAFs, without AOCs, could become Regional Engagement Headquarters.

Table 2-3. *CAOC/AOC Manning Proposal*

Numbered Air Force	***NAF/AFFOR Manning***	***AOC Peacetime Manning***	***AOC Wartime Manning***	***ARF UTC Manning***	***Active UTC Manning***	***Area of Operations***
7AF	99	QRP/350	TRP/800	250	200	U.S. Forces Korea
8AF	99	QRP/350	LRP/600	125	125	Pacific Command
9AF	99	LRP/600	TRP/800	200		Central Command
12AF	99	LRP/600	TRP/800	200		Southern Command, European Command (EUCOM)-Africa
16AF	99	QRP/350	LRP/600	125	125	EUCOM
Regional Engagement NAF						
3AF	99					
5AF	99					
11AF	99					
13AF	99					
Total	891	2250	3600	900	450	

The above number of AOCs is notional; however, three fundamental AOC requirements must be met when determining the number of AOCs that the Air Force can support: (1) The Air Force should ensure that all AOC Weapon System authorized manpower positions are filled and that this staff is fully trained in peacetime. They will provide a highly effective initial AOC combat capability until the augmentation forces arrive. (2) The Air Force Reserve and Guard should provide at least one-third of the wartime augmentees. They have provided high-quality, trained forces for theater AOCs. (3) If additional augmentees are required, they should be sourced from one of the other four fully trained AOC staffs. Following the above recommendations will fix most of our current AOC pick-up team deficiencies. SAB also believes that 8AF should be authorized a QRP so that they can train with an AOC staff and not become another "behind the Green Door" information operations organization. This would also allow 8AF to use collaborative tools to support other NAFs' peacetime training requirements.

Recommendations

Operationally test and validate the AOC UTCs based on a fully trained AOC staff and operationally effective technology (TBMCS)

Reduce the number of Air Force–provided AOCs to five and fully man this C^2 Weapon System (CSAF)

2.6.7 Time-Critical Targeting (TCT)

TCT will require a change in how the Air Force thinks about C^2. It will impact theater C^2 architecture design, modernization, and training. Although the TCT target set may be small or non-existent during the initial phase of an air campaign and overall is a fraction of total C^2 activity, TCT needs will push operational process improvement, pull technologies, and drive C^2 efficiency. An effective TCT capability will require superior coordination and C^2 of sensors

operating in air, ground, and space and simple intuitive tools for C^2 warriors to effectively find, fix, target, track, engage, and assess any target in the BattleSpace. Building an effective TCT capability can be the operational imperative that breaks down the organizational, technology, and process stovepipes that constrain C^2 effectiveness today. Aircraft weapon systems and munitions are designed and built to meet the most demanding missions. TCT, the military's most demanding C^2 mission, can and should be the driving force behind Air Force theater C^2 and ISR modernization and development. Developing a highly effective TCT capability will address most theater C^2 mission deficiencies that exist today. These capabilities include automated: intelligence preparation of the battlefield (IPB) development, effects-based targeting, and effects-based combat assessment. Other enhancements required include quality COP, enhanced information operations/ISR control cell, integrated database, Web-enabled and enhanced communications.

If C^2 warriors are able to successfully direct TCT engagements, C^2 in other theater mission areas will also significantly improve. The AC2ISRC's TCT analysis in its Family of Systems Requirements Document, 11 January 2000, and Strategy and Modernization Plan for Time Critical Targeting and Real Time Information to the Cockpit, 7 February 2000 (approved by the Air Force Requirements Oversight Council) is extensive and addresses the key end-to-end organization, process, and technology issues for fixing TCT. This analysis offers the Air Force a "silver thread" that can be used as the foundation for the joint and multi-Service theater C^2 system modernization.

Recommendations

Accelerate the multi-service and joint staffing of the Defeating Theater Time Critical Targets requirements document (AF/XO)

Develop and fund a TCT science and technology research and development program (SAF/AQ and AF/XP)

Fund and implement an effective TCT spiral development program (SAF/AQ, AF/XP, and AF/XO)

Fund and quickly transition operationally significant TCT technologies and TTPs to the field (SAF/AQ, AF/XO, and AF/XP)

2.6.8 Develop and Field the Battle Control Center (BCC)

The BCC concept will provide a modernized decentralized C^2 execution node for the Air Component Commander and CAOC. It should be organized to direct air battle execution¸ theater air defense, data link management, combat identification, and surveillance. The BCC should provide the Air Component Commander and JFC with a near-real time means of managing a single integrated air picture from air-, sea-, land-, and space-based sensors. Not only should the BCC provide the Air Component Commander with the personnel, TTPs, and equipment necessary to direct and control theater air operations, but the BCC should be equipped and trained to conduct limited theater planning, coordinate air operations with other joint and combined forces, and directly augment the Air Component Commander's airspace control and area air defense commander functions. When equipped and trained as described, the BCC can serve as a backup to the CAOC.

Recommendations

Accelerate modernization of the TACCS to ensure development and fielding of the BCC (initial operating capability [IOC] not later than 2005) (AF/XP, AF/XO, and SAF/AQ)

Manage the BCC as a weapon system (AF/XO)

2.6.9 Ensure Joint Interoperability

No single Service has the C^2, sensors, and weapons systems to accomplish all DoD missions. Therefore, each Service must be able to leverage another Service's situational awareness and weapons systems capabilities. Dynamic retasking of aircraft in support of commanders' priorities will require rapid access to appropriate databases to obtain the near–real time information that is essential for dynamic decision making. Joint interoperability also requires Air Force C^2 systems that are interoperable with GCCS and other service C^2 systems. Interoperable databases and appropriate data links are the foundation of this capability. The following initiatives are needed for the joint interoperability of the future TACCS:

1. **Develop and refine the Joint COP:** Air Force and Army information systems cannot now rapidly exchange data in support of dynamic retasking. There is a need to resolve interoperability issues between TBMCS and the Army Battle Control System (ABCS). Furthermore, there is a need to develop joint TTPs that outline how all service sensors support the near–real time COP and targeting.

2. **Develop procedures for cross-cueing of Service ISR assets:** ISR assets currently work as stove piped systems, but target attack often requires cross-cueing of other ISR assets to verify and/or refine information. New procedures are needed to cross-cue sensors and, if required, provide continuous target coverage until the mission is completed. For example, the AOC should have data links to the Corps' Deep Operations Coordination Cell (DOCC) to nominate targets for Army ISR asset coverage. Likewise, the DOCC should be able to nominate targets for Air Force ISR asset coverage.

3. **Refine ATO procedures:** While the Air Force, Navy, and Marine Corps all control aircraft by tail number, the Army controls helicopters by units as a subset of the combined arms team near the forward line of troops (FLOT) or when attacking targets beyond the FLOT. The 72-hour ATO process appears to be too restrictive to accommodate helicopter missions that are responding to the ground commander taskings. However, helicopters need to be included in the ATO process to prevent fratricide and coordinate Suppression of Enemy Air Defenses (SEAD) and Combat Search and Rescue (CSAR). Interoperable information systems should permit the addition of helicopters to the ATO on relatively short notice. For example, the DOCC could provide placeholders 30-plus hours in advance and wait until the last possible time (for example, 6 hours) to provide specifics. We recommend that procedures be developed between TBMCS and the Advanced Field Artillery Tactical Data System (AFATDS) to accomplish the short-notice inclusion of helicopters in the ATO.

4. **Complete the development of TBMCS—AFATDS interoperability:** AFATDS–TBMCS interoperability is essential for integrating battle plans and coordinating situational awareness. The effective exchange of information between the AOC and DOCC will rapidly

improve joint target-weapon pairing capability. The DOCC can also quickly receive the ATO and ATO updates from the AOC and pass Candidate Targeting Lists to the AOC.

5. **Ensure TBMCS can access the Army's All Source Analysis System (ASAS) data:** ASAS can contribute to the air COP by providing information for IPB, situational awareness, and near–real time retasking of strike aircraft. Interoperability gateways will permit passing of tactical electronic intelligence reports and other tactical reports, as well as interactive TBMCS–ASAS databases.

6. **Improve air-ground operations situational awareness:** CAS must have situational awareness on the location of friendly ground forces to prevent fratricide and improve support to the ground force commander. The Army and Air Force should establish a gateway between the Army's Enhanced Position Location Reporting System Enhanced Position Location Reporting System (EPLRS)/Virtual Message Format (VMF) ground network and the Joint Data Network so that CAS aircraft have accurate locations of friendly ground forces. The Army should also be encouraged to modify its VMF message formats to include altitude and height information. This would result in a more accurate location of ground forces for CAS aircraft.

7. **Refine joint airspace clearance procedures:** There appears to be a need to clarify the Army Tactical Missile System (ATACMS) immediate and preplanned fires procedures within Joint Doctrine.

8. **Improve mission planning, rehearsals, and retasking:** JFCs lack the ability to conduct real-time mission planning before redirection of strike aircraft. The Rome Laboratory's Information for Global Reach program may allow ground commanders to conduct collaborative planning with air commanders while missions are en route to the theater of operations.

9. **Place more emphasis on joint training:** We recommend that the numbered air forces and land components and corps participate in peacetime ATO development. AOCs should also participate in Army Corps Warfighter Exercises.

Recommendations

Refine air–ground operation procedures and ensure interoperability of C^2 systems.

- *Ensure that TBMCS and ABCS are interoperable (AF/XO)*
- *Develop operating procedures for the AOC to request sensor support from Army ISR assets and for the DOCC to request sensor support from AOC ISR assets (AF/XO)*
- *Refine ATO procedures to allow reduced timelines for inclusion of Army helicopters in the ATO process for SEAD and CSAR support. Consider using AFATDS connectivity to TBMCS to expedite the process. (AF/XO)*
- *Complete the development of gateways between TBMCS and AFATDS (SAF/AQ)*
- *Establish a gateway between EPLRS/VMF and the Joint Data Network to provide CAS aircraft with accurate locations of friendly ground forces (SAF/AQ)*
- *Refine joint airspace clearance procedures to include ATACMS immediate and preplanned fires within Joint Doctrine. Consider the TBMCS–AFATDS and the TBMCS–Tactical Airspace Integration System linkages as a means to expedite clearances. (AF/XO)*

- *Place more emphasis on joint training to include AOC participation in all Army Corps Warfighter Exercises (AF/XO)*

Interoperability issues are explored in detail in the Report of the Interoperability Panel, Chapter 3.

2.6.10 Air Force Forces

Operations from World War II to the present continue to point to a lack of progress in defining, organizing, and institutionalizing a theater-smart highly trained AFFOR capability. More attention is needed for the maturation and development of the AFFOR organizational concept, staffing, C^2 training and exercises, decision support systems, processes, and UTCs.

Senior leadership must define the AFFOR organization and develop a distributed operations concept using forward elements and reachback locations. The AFFOR staff is an operational Air Force wartime capability and must be established and ready to execute its mission in direct support of deployed theater aerospace forces. However, the Air Force has often used existing resources and a pick-up team when an operation commences. AFFOR staff must be assigned to an AFFOR UTC and receive effective training to carry out their mission. Manning for AFFOR UTCs should be sourced from previously identified and trained personnel from the engaged NAF staff, non-engaged NAF staffs, and MAJCOM staffs. These individuals must train regularly to perform AFFOR functions. Commanders may tailor and position AFFOR C^2 centers to support contingencies.

AFFOR functions and responsibilities are not well defined, understood or implemented: The corporate Air Force needs to educate airmen on the difference between the Service C^2 functions of the AFFOR staff (HQ) and the "operational" C^2 element, the J/CAOC. COMAFFOR requires a capable staff to plan, deploy, employ, sustain, and redeploy aerospace forces to carry out the JFC's mission objectives. This is an enduring requirement for deployed aerospace forces and is separate from the responsibilities of a dual-hatted COMAFFOR's JFACC.

AFFOR functions should be well defined: NAF staffs have competing missions in supporting both their J/CAOC and the AFFOR responsibilities. The current Air Force structure and CONOPS assume that NAFs provide the staff for an AFFOR forward capability. The NAFs are not staffed or trained to carry out the AFFOR role.

The Air Force must decide how to transition AFFOR support from peacetime to wartime, the organization responsible to staff the AFFOR, and AFFOR functions that can be deployed forward. All other AFFOR functions should be performed in the rear. The concept for Operational Support Centers (OSC) is sound for reachback support.

AFFOR documentation and guidance are lacking: An agreed-upon AFFOR "roadmap" does not exist. Over the past 2 years, the AC2ISRC has led an AFFOR baseline effort. Many documents were written. To date, the UTCs are registered, but no unit is responsible for implementing the UTCs and Air Force approval of the AFFOR CONOPS, operational guidance, and training has not been achieved.

AFFOR organizations, systems, processes, and allocation of manpower must be defined before training programs are built. The AFFOR baseline team started from scratch and developed a

CONOPS and an AFI for operational guidance; TTPs are in development. Once staffed and approved, development of executable AFFOR UTCs and identification of AFFOR training needs will follow.

General officer ownership and guidance: Air Force leadership must identify an advocate to define AFFOR mission requirements and capabilities. Air campaign success is depends on having the right support, at the right time, in the right place. The AFFOR provides this support. As such, AFFOR is a capability the Air Force needs to support, develop, and institutionalize.

Recommendations

Identify an Air Staff advocate for AFFOR C^2 requirements and capabilities (CSAF)

- *Define and fully implement the AFFOR organizational concept described above (CSAF)*
- *Identify and train AFFOR staff members; NAFs, MAJCOMs, and/or in-place OSCs (AF/XO and AF/IL)*
- *Identify AFFOR/AOC functional relationships (AF/XO and AF/IL)*
- *Develop, staff, and approve CONOPS, AFI (Vol. 1 and III), TTPs, executable UTCs, and logistics detail (AF/XO and AF/IL)*
- *Determine requirements and implement regular training exercises for AFFOR staffs (AF/XO and AF/IL)*

Further define the forward/reachback concept for AFFOR operations (AF/XO and AF/IL)

2.7 GCCS-AF

To date, the Air Force has produced stove piped legacy C^2 systems across numerous mission areas such as mobility, space, strategic, ISR planning and weapons control, mission planning, theater battle management, and agile combat support. Separate acquisition and support efforts have led to duplicative information views across mission areas and different computing infrastructures. These stove-piped C^2 systems have limited interoperability. This results in multiple C^2 systems within C^2 centers that provide inconsistent information views and produce complex technology environments for the operator.

Most of the stove-piped C^2 systems can be attributed to multiple C^2 management structures, limited cross-flow of requirements, and lack of a consolidated C^2ISR enterprise-wide view of C^2. These separate management processes have resulted in stove-piped system production, duplication across mission areas, questionable use of resources (funding, manpower), and fragmented information to the warfighter. The separate processes that manage Air Force joint requirements for GCCS and TBMCS are an example of multiple C^2 management structures.

2.7.1 Defining GCCS-AF

GCCS-AF should be thought of as the Air Force's implementation of the Joint GCCS program, and it should be used to manage and define the automated C^2 and ISR mission tools for Air Force strategic, theater, wing, and unit commanders.

Merging C^2 and ISR weapons system applications into a single GCCS-AF C^2 system will provide the warfighter with a common integrated and interoperable family of C^2 applications that can display common information on common hardware. GCCS-AF should be linked by the

global information grid and enable collaboration with all warfighters, including the CINCs and other Services.

2.7.2 Implementing GCCS-AF

Movement to a single Air Force C^2 system in GCCS-AF and establishment of a single C^2 management oversight structure are critical to the Air Force's C^2 enterprise. Several systems must be folded into GCCS-AF in the near term and become part of the JBI as it evolves. Figure 2-7 depicts how existing systems need to be integrated into GCCS-AF.

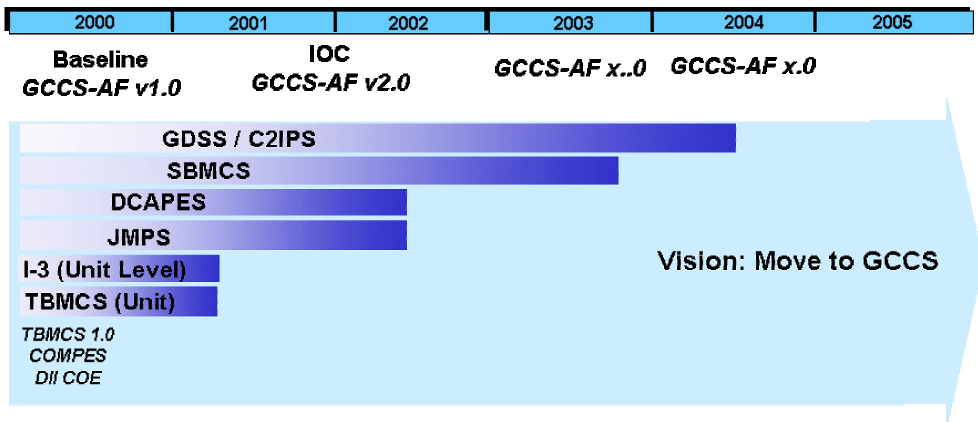


Figure 2-7. *GCCS-AF*

There also needs to be an Air Force policy decision that directs GCCS-AF. The integration of all future Air Force unit- and force-level applications (for example, mission planning, crisis planning, space battle management, and mobility planning and execution applications on the GCCS-AF software and hardware infrastructures) should be clearly stated in the policy directive. This will produce an integrated C^2 system across Air Force C^2 domains and link the Air Force by 2005.

The near-term technical strategy for an integrated GCCS-AF should include migration to the joint GCCS common integration framework—the Defense Information Infrastructure Common Operating Environment (DII COE) Level 6. This should continue for the short term; however, the mid- to long-term solution is a Web-based integration framework, which, in turn, will enable the development of a full JBI capability. This concept was described in the SAB's December 1998 Study, *Information Management* and December 1999 Study, *Building the Joint Battlespace InfoSphere*.

Recommendations

Designate GCCS-AF as the Air Force C^2 system (CSAF)

- *Develop and expedite transition planning to consolidate C^{2}ISR mission functions into GCCS-AF (SAF/AQ)*
- *Establish a single management oversight process to represent the Air Force in joint GCCS management (AF/XO)*

- *Establish a C^2 integration program that is empowered to integrate activities between the various C^2 centers and nodes (SAF/AQ)*

2.8 Migrating to the Joint Battlespace InfoSphere

JBI is a proposed improvement for C^2 that recognizes and exploits the design and development processes that have been sweeping across the commercial information technology markets. It represents a major evolutionary milestone in information system design and offers operational, system, and technical improvements. Currently there is no Air Force program that provides for developing, acquiring, or fielding the JBI. The Air Force needs to establish a JBI program, and it is our recommendation that it be an infrastructure element of the GCCS-AF and Global Combat Support System-Air Force programs. Resolving the technical issues involved with migrating from today's GCCS DII-COE design construct to the JBI design construct will require that it be closely linked to the GCCS program. Close cooperation with Defense Information Systems Agency (DISA) and DII COE governing bodies will also be required.

Figure 2-8 depicts the progression in software design styles. Previously, C^2 systems were built using modular software in which the system comprised software code that was easily distinguished as separate software modules. Recently, a more sophisticated modular software approach has been used in which the applications code is distinguished from the infrastructure code. This infrastructure code provides services required by C^2 applications that ride on the code; the infrastructure code is built using common commercial sources. The DISA DII COE is an example of this infrastructure code that is used for C^2 systems development today. Interoperability among C^2 systems was thought to be easier if systems used a common infrastructure. However, it is becoming widely accepted that a common DII COE infrastructure is insufficient for achieving interoperability. Common data semantics, or a means for converting different data structures, is also needed. We also believe that the burden of maintaining common versions of DII COE across different C^2 and ISR systems is considerably more demanding than maintaining common Web-based protocols for information exchange. This increasing cost for maintaining the DII COE will motivate the development of the JBI.

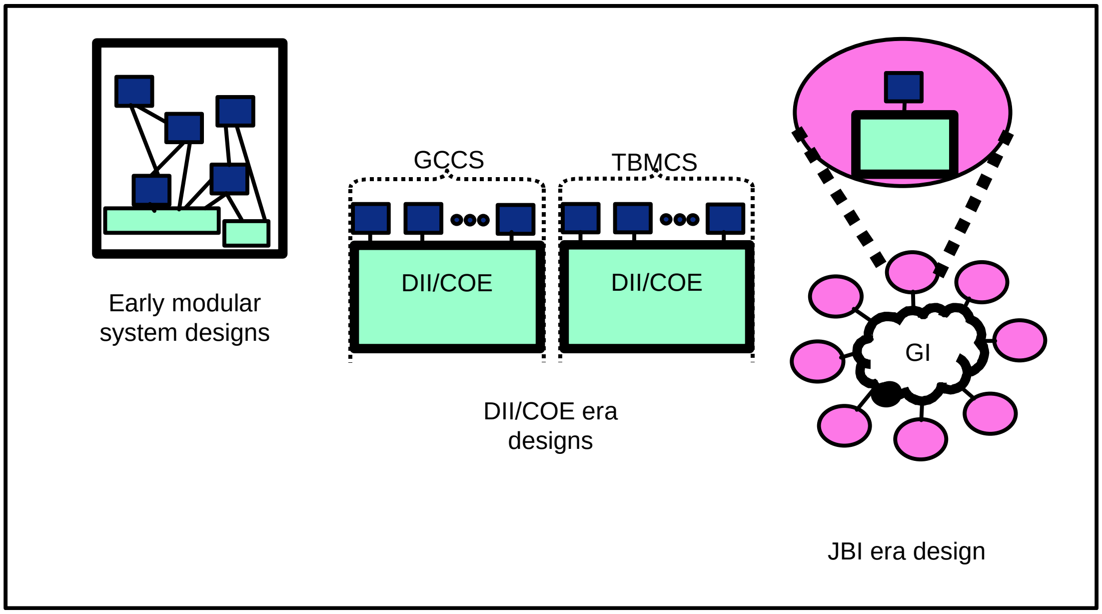


Figure 2-8. *Contrasting Styles of Design*

The JBI enables interoperability without requiring the same version of DII COE across all C^2 systems. As a result, development of the JBI is becoming a more attractive means for achieving interoperability. The prime technical mechanism that allows systems to participate in the JBI is the adoption of a Web-enabled information exchange process. Today's web technology entails publishing information using Extensible Markup Language (XML) and using subscriptions or queries to retrieve the information. Existing systems will be able to migrate relatively quickly to the JBI by adopting the XML approach. Future systems will be able to bypass portions of the process described above by having capability modules connect directly to the JBI. As more and more systems adopt the Web-enabled structure as an internal software construct, the size of add-on systems will diminish because the JBI's individual functionality applications, "fuselets," will offer a flexible, easily integrated, and easily upgraded and maintained capability that will replace the older add-on systems. In other words, application modules from existing systems can be migrated over time from residence within a DII COE infrastructure design towards residence within an InfoSphere design. The exchange of information among modules or systems will be easier to manage when those exchanges are accomplished through Web-enabled interfaces, rather than through adherence to common (that is, the same) components.

It should be specifically pointed out that adherence to a DII COE configuration is good from an integrated product standpoint. For example, within an application, the use of standard elements, standard interfaces, standard protocols, etc., is good practices and should not be abandoned. The SAB suggests that it is not necessary for all C^2 systems to use the same version of the DII COE and is not recommending abandonment of the DII COE altogether. Different versions are OK when using the JBI strategy to satisfy the interoperability objective. However, it is also important to adhere to good software engineering practices and use a layered architecture and standard components, such as can be found in individual versions of the DII COE, to develop individual system or application modules.

We recommend that this JBI migration be funded by one PE and be managed by a single System Program Office (SPO) that is devoted to fielding Air Force enterprise-wide interoperable C^2. Thus it makes sense to consider consolidating existing programs, such as the TBMCS, along with infrastructure evolution programs, such as GCCS-AF, into a single office that is devoted to the growth and fielding of the JBI.

Recommendations

Develop a long-term JBI strategy and fund it.

- *Use an internet or Web-based implementation strategy (AF/XO and SAF/AQ)*
- *Use the Web and related technologies (such as XML) emerging from the commercial world for JBI development (SAF/AQ)*
- *Require an open system design for JBI development (SAF/AQ)*

Establish a SPO that is responsible for fielding Air Force enterprise-wide interoperable C^2 (SAF/AQ)

2.9 Summary

The Air Force vision of "well-equipped C^2 centers collaborating globally in support of the CINCs" can be rapidly achieved if senior Air Force leadership strongly endorses the need for an enterprise-wide C^2 capability. The Air Force must restructure the way C^2 programs are managed and resourced, and leadership must clearly speak out about their dedication to achieving an enterprise-wide C^2 capability at every opportunity. In this chapter we have defined the current C^2 system and provided a proposal for how the Air Force can achieve an enterprise-wide C^2 capability by 2005. We have provided our views on areas that the SAF, Air Staff, and MAJCOM staffs should focus on in starting down a C^2 modernization journey. The journey of achieving an effective distributed, collaborative, enterprise-wide C^2 capability that allows C^2 centers to collaborate globally in support of the CINCs is one of the most important journeys the Air Force needs to take in the 21st century.

Reference Appendix 2A through 2C for the C^2 System Definition and Operational Concept Panel's Charter, membership, and fact-finding visit schedule.

Appendix 2A
C^2 System Definition and Operational Concept Panel Charter

Serve as the focal point of the study for the description and review of

- The current command and control concepts and procedures
- The current C^4ISR systems and their supporting infrastructure

Define the needed future capability for command and control (circa 2005) and develop a set of recommendations on how the Air Force can achieve these capabilities. This includes changes in the existing systems or ongoing programs through the introduction of new technology (as defined by the Technology Panel) and changes in training and personnel policies (as articulated by the People and Organization Panel). Such changes may require enhancements of the acquisition process (as addressed by the Acquisition and Program Management Panel).

Examine the command and control process both from the corporate Air Force level and from the operational level, particularly in joint and combined operations.

Address the following points

- Identify the Air Force concepts of operations for C^2
- Identify the current C^2 elements and planned improvements that will have an impact on operations by 2005
- Identify the missions the Air Force is expected to carry out in this timeframe
- Identify the changes in the planning-execution-assessment cycle

Recommendations for the short-term improvements should be consistent with the Air Force's long-term command and control goals.

(This Page Intentionally Left Blank)

Appendix 2B
C^2 Concept and System Definition Panel Membership

Lt Gen Joseph E. Hurd, USAF (Ret), Chair
Private Consultant

Maj Gen John A. Corder, USAF (Ret)
Private Consultant

Mr. Troy Crites
Sparta, Inc.

Dr. Llewellyn S. Dougherty
Director of Technology
Raytheon Electronic Systems

Mr. Jim Hale
Private Consultant

Maj Gen John Hawley, USAF (Ret)
Private Consultant

David Hess
AC2ISRC
MITRE

Col Stu Kraft, USAF (Ret)
Director, Business Development
Northrop Grumman/Logicon Technical Solutions

Maj Robert Lanahan
Branch Chief, Future Communications Systems
National Reconnaissance Office

Prof. Alexander H. Levis
Professor
George Mason University

Prof. Christine Mitchell
Professor
Georgia Tech

Maj Robin Morris
AC2ISRC/C2A

Col Wayne Ranne, USAF (Ret)
Private Consultant

Col Mike Reavey, USAF (Ret)
Private Consultant

Mr. Skip Saunders
Executive Director
MITRE

Prof. Gene Spafford
Professor
Purdue University

Col Carl Van Pelt, USAF (Ret)
Private Consultant

Lt Gen Ronald Watts, USA (Ret)
President
Leadership Development Services

Executive Officer: Capt Larry W. Norman, Jr., AC2ISRC/C2RO
Technical Writer: Maj Thomas Schorsch, USAFA

Appendix 2C
C^2 Concept and System Definition Panel Visits

Hurlburt AFB, C^2TIG, 3-4 May 00

Langley AFB, Air Combat Command, 11-13 April 00

Nellis AFB, Spring Board Meeting, 25-27 April 00

Las Vegas, Agile Combat Support Conference, May 00

Boeing, Seattle, WA, 29-30 June 00

Davis Monthan AFB, 7-9 June 00

National Reconnaissance Office, Capability and Interoperability, 16-17 May 00

Defense Advanced Research Projects Agency, Capabilities, 18 May 00

Rome Research Site, Capabilities, 12 June 00

Hanscom AFB, Programs Review, 13-14 June 00

San Diego, C^2 on Coronado, 17 July 00

SAB Summer Session, San Jose, CA, Final Report, 10-21 July 00

(This Page Intentionally Left Blank)

Appendix 2D
C^2 Weapons System Management—"Matrix Table"

	CONOPs	ORD	Program Element	PMD	Acquisition Program Manager	Panel	MAP/ MSP	C4ISP
C2 Weapon System								
AOC	TACCS / AOC	TACCS	AOC	TACCS / AOC	CAF C2	C4I	TACCS MAP	AOC
AFSPACE AOC	AFSPACE AOC	AFSPACE AOC	AFSPACE AOC	AFSPACE AOC	Space & Nuc Det	C4I	Space C2	AFSPACE AOC
ASOC	TACCS / ASOC	TACCS	TACCS	TACCS / ASOC	CAF C2	C4I	TACCS MAP	ASOC
BCC (CRC/CRE)	TACCS / BCC	TACCS	TACCS	TACCS / BCC	CAF C2	C4I	TACCS MAP	BCC
TACP	TACCS / TACP	TACCS	TACCS	TACCS / TACP	CAF C2	C4I	TACCS MAP	TACP
Airborne FAC	TACCS / FAC	TACCS	TACCS	TACCS / FAC	CAF C2	C4I	TACCS MAP	FAC
TACC	Mobility C2	Mobility C2	Mobility C2	Mobility C2	Mobility C2	C4I	Mobility C2 MAP	TACC
OSC (3) (AFFOR)	TACCS / OSC (AFFOR)	OSC (AFFOR)	OSC (AFFOR)	TACCS / OSC(AFFOR)	OSC (AFFOR)	C4I	TACCS MAP & ACS MSP	OSC (AFFOR)
AFIWC	AFIWC	AFIWC	AFIWC	AFIWC	IW	C4I	IW MAP	AFIWC
ABCCC	TACCS / FAC	ABCCC	ABCCC	TACCS / ABCCC	CAF C2	C4I	TACCS MAP	ABCCC
AWACS Backend	TACCS / AWACS	AWACS	AWACS	TACCS / AWACS	AWACS	Sensor	TACCS & ISR MAPs	AWACS
Joint Stars Backend	TACCS / JS	Joint Stars	Joint Stars	TACCS / Joint Stars	Joint Stars	Sensor	TACCS MAP	Joint Stars
Rivet Joint Backend	TACCS / RJ	Rivet Joint	Rivet Joint	TACCS / RJ	Rivet Joint ?	Sensor	TACCS MAP	Rivet Joint
USSPACE / NORAD	Space C2 & Homeland Defense	ISC2 / N/UWSS	ISC2	ISC2	Space & Nuc Det	C4I	Space C2 MAP	N/UWSS
STRATCOM Cmd Center	STRAT C2	STRAT C2	STRAT C2	STRAT C2	Space & Nuc Det	C4I	Strategic C2 MAP	SWPS
MCCC	STRAT C2, SPACE C2 & Homeland Defense	MCCC	ISC2	MCCC	Space & Nuc Det	C4I	Strategic C2 MAP	MCCC
NMCC		NMCC	NMCC	NMCC		C4I		
RAOC/SAOC	Homeland Defense	RAOC/SAOC	RAOC/SAOC	RAOC/SAOC	CAF C2	C4I	Homeland Defense MAP	
PED Centers(DCGS, UES, etc)	PED	PED	PED	PED	GCCS-AF Integration (CX)	C4I	ISR MAP	PED
C4I Applications Supporting the C2 Weapons System								
GCCS-AF	GCCS-AF	GCCS-AF	GCCS-AF	GCCS-AF	GCCS-AF Integration (CX)	C4I	N/A	GCCS-AF
GCSS-AF	GCSS-AF	GCSS-AF	GCSS-AF	GCSS-AF	GCCS-AF Integration (CX)	C4I	ACS MSP	GCSS-AF
GCCS-AF Weapons Control	GCCS-AF Weapons Control	GCCS-AF Weapons Control	GCCS-AF Weapons Control	GCCS-AF Weapons Control	GCCS-AF Integration (CX)	C4I	TACCS MAP	
C4I Communication & Software Infrastructure Supporting the C2 Weapons System								
Tactical Comm	Comm	Tactical Comm	Tactical Comm	Tactical Comm	Infrastructure	C4I	Infrastructure MSP	multiple
Base Level Comm	Comm	Base Level Comm	Base Level Comm	Base Level Comm	Infrastructure	C4I	Infrastructure MSP	multiple
Long Haul Comm	Comm	Long Haul Comm	Long Haul Comm	Long Haul Comm	Infrastructure	C4I	Infrastructure MSP	multiple
SATCOM	Comm	SATCOM	SATCOM	SATCOM	Infrastructure	C4I	Infrastructure MSP	SATCOM
Information Infrastructure & Integration of the C2 Weapons System								
Common Information Management (CIM)	CIM	CIM	CIM	CIM	GCCS-AF Integration (CX)	C4I	Common Information Management MSP	N/A
Datalinks	CIM	Datalinks	Datalinks	Datalinks	GCCS-AF Integration (CX)	C4I	Common Information Management MSP	N/A
JNTCCS (Joint)	CIM	JNTACCS (Joint)	JNTACCS		GCCS-AF Integration (CX)	C4I	Common Information Management MSP	N/A
AF Sensors providing critical information to the C2 Weapon System								
All Sensors (sapce, airborne & ground)	Sensor	Sensor	multiple	multiple	multiple	Sensor	ISR MAP	One for each Sensor
NOTES:								
There is an Aerospace C2 CRD over all the listed ORDs; these will contain the total list of Interoperabiltiy KPPs (IERs between nodes)								
There is a capstone PMD over all the listed PMDs directing cross program roadmaps to achieve the CRD capabilities								

(This Page Intentionally Left Blank)

Chapter 3
Report of the Interoperability Panel

3.1 Introduction

The future of America's military success, and thus of its national security and ability to achieve national objectives, depends critically on information-enabled operations.[1] Information dominance—the ability to employ information to achieve decisive battlespace advantage while denying such use to an adversary—is one of the central tenets of joint doctrine, strategy, and tactics. Achieving this advantage means that individual Service, joint, and coalition forces must be able to gather, share, process, interpret, and use information and do so with superior speed, reliability, security, and resistance to enemy actions. As military history has repeatedly shown, the side with an information advantage will usually prevail, even against superior numbers.[2] This is increasingly the case in modern operations and it applies to every level of the spectrum of conflict.

Rapidly advancing technology—from sensors to communications to computers and displays—provides much of the foundation for Information Dominance. Yet decades-old problems with incompatible equipment, divergent definitions and uses of data, uncoordinated procedures, and other aspects of information sharing continue to plague U.S. and allied military forces. We have repeatedly found ourselves enjoying an advantage in the sophistication of our technology, only to have that advantage reduced or negated by a lack of interoperability. Recognizing the seriousness and importance of this problem, this Air Force Scientific Advisory Board (SAB) study has devoted a specialized panel to the topic and charged it with determining the sources of non-interoperability and the immediate and longer-term steps needed to correct these shortfalls.

Interoperability means the ability to link the right people and systems, at the right time, in one-on-one, one-to-many, or many-to-many situations; and to pass consistent data that converts to useful information and thence to actionable knowledge that enables cooperative decision-making and resultant action. A bit more formally, the authoritative definition of interoperability is

> 1. The ability of systems, units or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together. 2. The conditions achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users.[3]

The key words are "operate effectively together." As we have learned in this study, passing messages and data is only the beginning of interoperability, and even the ponderous definition just cited only hints at the complexity of the problem of reliably achieving synchronized,

[1] *Joint Vision 2020*, Chairman, Joint Chiefs of Staff, 2000; *Vision 2020: Global Vigilance, Reach and Power*, General Michael E. Ryan, Chief of Staff, U.S. Air Force, and F. Whitten Peters, Secretary of the Air Force.

[2] As one example, the unauthorized extended absence of Jeb Stuart's cavalry just prior to the battle of Gettysburg deprived Lee of critical intelligence and is considered a major contributor to his defeat. Millennia earlier, Sun Szu wrote, "Act after having made assessments. The one who first knows the measures of far and near wins—this is the law of armed struggle,"—*The Art of War*, Thomas Clearly, trans. (Boston: Shambala Publications 1988).

[3] Joint Publication 1-02, *DoD Dictionary of Military and Associated Terms*.

mutually supportive action among elements of a force. Interoperability has a myriad of facets, not only system to system, but also command to command, Service to Service, joint to component forces, and joint to coalition partners. Figure 3-1, drawn from the perspective of a theater Air Operations Center (AOC), suggests a few of the places where interoperability is required. Interoperability requirements escalate dramatically when we look at joint and coalition forces and consider connectivity and interoperability among service entities and across warfare areas. In combat, the Air Force works in the air superiority, close air support, and ground strike warfare regimes and meet air mobility, airspace management, aerial refueling, and other requirements. In a joint environment, Air Force units are joined by the Navy in both air superiority and ground strike, as well as by the Army and Marine Corps in ground strike. With the burgeoning role of naval surface and undersea fire support from off-shore, the Navy's role in ground strike has now extended beyond the functions of Naval Aviation, adding yet another variable. When allied forces join the mix, still other disconnects, ranging from equipment peculiarities to differences in policy and doctrine, can arise in the interoperability equation of joint and coalition warfare.

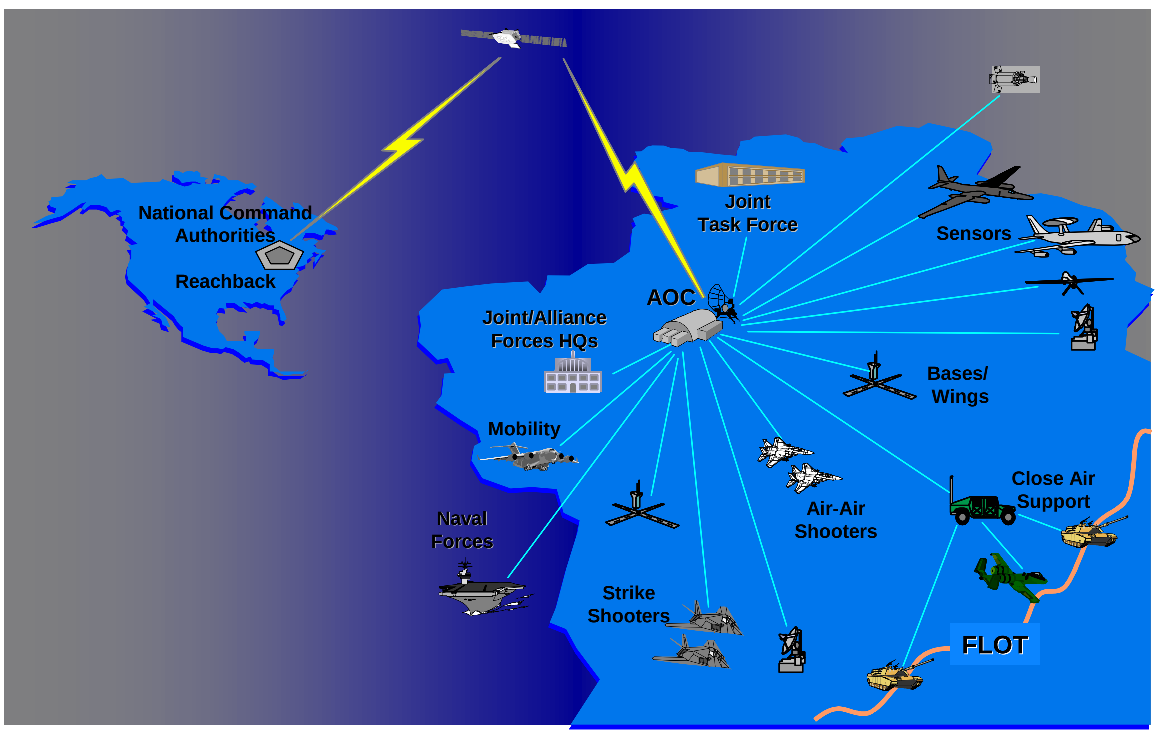


Figure 3-1. *Pervasive Needs for Interoperability Throughout a Joint/Coalition Force*

We have proved in recent contingencies that we could get the job done by a joint force without an advanced state of interoperability. But we cannot assume that we can continue to do so indefinitely, regardless of opponents and scenarios, as the rest of the world closes the gap in applying information technology (IT) to warfare. Information dominance will be increasingly critical to a Joint Force Commander, and interoperability is a prerequisite. The main focus is on mission success, but the incentives for pursuing joint interoperability range from minimizing the cost to deploy, operate, and support forces to coping with the political and policy realities of a coalition. Thus, while it is reasonable for the Air Force to concentrate efforts on improving the

interoperability of its own systems and units, there must be an aggressive parallel effort to achieve joint and coalition interoperability. At the very least, we must guard against any course of action that will further complicate the joint and coalition interoperability problem.

The Interoperability Panel brought together both senior military officers and technical experts in the various disciplines involved. Panel members included retired Air Force and Navy flag officers, and we had the benefit of the insight of the Army Science Board participants in the study, while the chairman and other panel members are active in interoperability efforts involving our allies. We went to great lengths to visit the main organizations working these issues in all three Services and to understand their programs and priorities. In the sections that follow, we present our analysis of the technical, operational, organizational, and other barriers to interoperability and our focused recommendations on how they should be addressed. Inevitably, many of our findings and recommendations overlap those of other panels and are reflected in their reports as well.

3.2 Approach and Visits

The panel charter and membership are given in Appendices 3A and 3B. The approach taken by the panel to address these issues can be summarized as follows:

- Emphasize contacts with primary organizations in all three Services charged with implementing interoperable command, control, communication, computer, and intelligence, surveillance and reconnaissance (C^4ISR) capabilities and the expertise of panel members and other study participants with joint and coalition experience
- Collect data and informed opinion on technical, operational, organizational, doctrinal and procedural aspects of interoperability, especially those factors that defy simple solutions through standardization and equipment commonality
- Develop insight into perspectives, goals, and plans affecting interoperability of all Services and allied nations
- Identify key interoperability issues and assign panel members to focus on these; areas include information modeling and engineering, system and system-of-systems architectures, data links and other communications, human factors and human-machine integration, joint and coalition interoperability, interoperability factors in system requirements definition and system acquisition, ways to achieve the required central oversight and enforcement of interoperability actions, and long-term strategies to enhance interoperability
- Evaluate the Joint Battlespace InfoSphere (JBI) as a potential solution to interoperability problems and the steps required in evolving the current C^4ISR environment to the JBI
- Interact extensively with other panels to gather information and to ensure that interoperability considerations are captured in the overall study

The panel conducted an extensive information-gathering campaign. The following is a synopsis of the visits, many of which were joint meetings with one or more other panels.

Table 3-1. *Interoperability Panel Visits*

Dates	*Organization/Location*	*Topics*	*Other Panels*
Mar 20-21	Command and Control (C^2) Training and Innovation Group (C^2TIG), Hurlburt Air Force Base (AFB)	Aerospace Command and Control Intelligence, Surveillance, and Reconnaissance Center (AC2ISRC) story, Electronic Systems Center (ESC) C^2 perspective, Joint Surveillance Target Attack Radar System, C^2ISR acquisition, C^2 Battlelab, Joint Expeditionary Force Experiment (JEFX) 2000	All
April 10-12	Joint Forces Command, AC2ISRC, Joint Warfare Center, Joint Battle Center, Hampton, VA	Air Combat Command (ACC) lessons learned, time-critical targeting, AOC weapon system, C^2 tools, data links, Air Force experimentation	All
April 25-27	Red Flag, Nellis AFB	Air Warfare Center, Space Warfare Center, Red Flag, ESC programs, Boeing independent research and development	All
May 16-17	National Reconnaissance Office (NRO), Chantilly, VA	NRO programs	Technology
May 18	Lockheed Martin, Office of the Assistant Secretary of Defense: Command, Control, Communications, and Intelligence (OASD/C^3I), Joint Strike Fighter (JSF) Program Office, Crystal City, VA	Project Rainbow, OASD/C^3I strategic process improvements	None
June 12	Air Force Research Laboratory/Information Directorate (AFRL/IF), Rome, NY	AFRL/IF programs	Technology
June 13-14	ESC; Woburn, MA	ESC programs	All
June 21	Headquarters U.S. Army/ DISC4, Pentagon	Army enterprise architecture, Army battlefield digitization, data models	Technology, People & Organization
June 26-27	Space and Naval Warfare System Command (SPAWAR) System Center, SPAWAR Acquisition	Navy C^4ISR programs, data nodels, facilities, architectures	Technology
June 30	Army Program Executive Officers (PEO)/C3S, Ft. Monmouth, NJ	Army C^4ISR programs, architectures, battlefield digitization, data models	None
July 17	USS Coronado, San Diego	Navy command ship and systems	All

3.3 Findings and Discussion

3.3.1 The Meaning and Importance of Interoperability

In introducing this chapter, we stressed the critical importance of Information Dominance, and thus of interoperability, to success in current and future military operations. To amplify and substantiate this general assertion, consider the following circumstances on a modern battlefield, which may range in scope from a major theater of war down to an apartment building where a hostage is imprisoned.

- Unprecedented demands for exquisitely precise application of military force are becoming routine. These derive from the needs of effects-based operations, from the political unacceptability of collateral damage and civilian casualties, from hostile use of deception and concealment, and from many other factors. The result is a critical need to collect extensive, current, high-quality information on targets and their contexts; to formulate and distribute effective mission tasking; to coordinate and control multiple platforms and warfighters in tightly timed sequences; and to rapidly assess the status and results of operations. Each step of this chain demands seamless interoperability across and within all echelons of the force.
- Friendly-fire episodes are among the most abhorrent events in war, yet they persist as a consequence of breakdowns in critical information processes. The best insurance against these tragedies is the ability to maintain a comprehensive situational awareness picture of the battlespace and to distribute the appropriate elements of that picture to every participant in real time. This, in turn, raises a typical interoperability challenge that today is only partially met.
- In the post–Cold War era, no aspect of military capability, not even operational effectiveness, is more important than affordability. An obvious cost containment strategy is to maximize the use of common material solutions across Services and allied nations. Yet differences in policy, doctrine, and tactics repeatedly frustrate this approach. Moreover, failure to consider interoperability from the earliest stages of defining system requirements and planning and executing acquisition programs virtually guarantees later problems, often with expensive fixes. These are interoperability problems as surely as any technical incompatibility of equipment, and may be harder to solve.

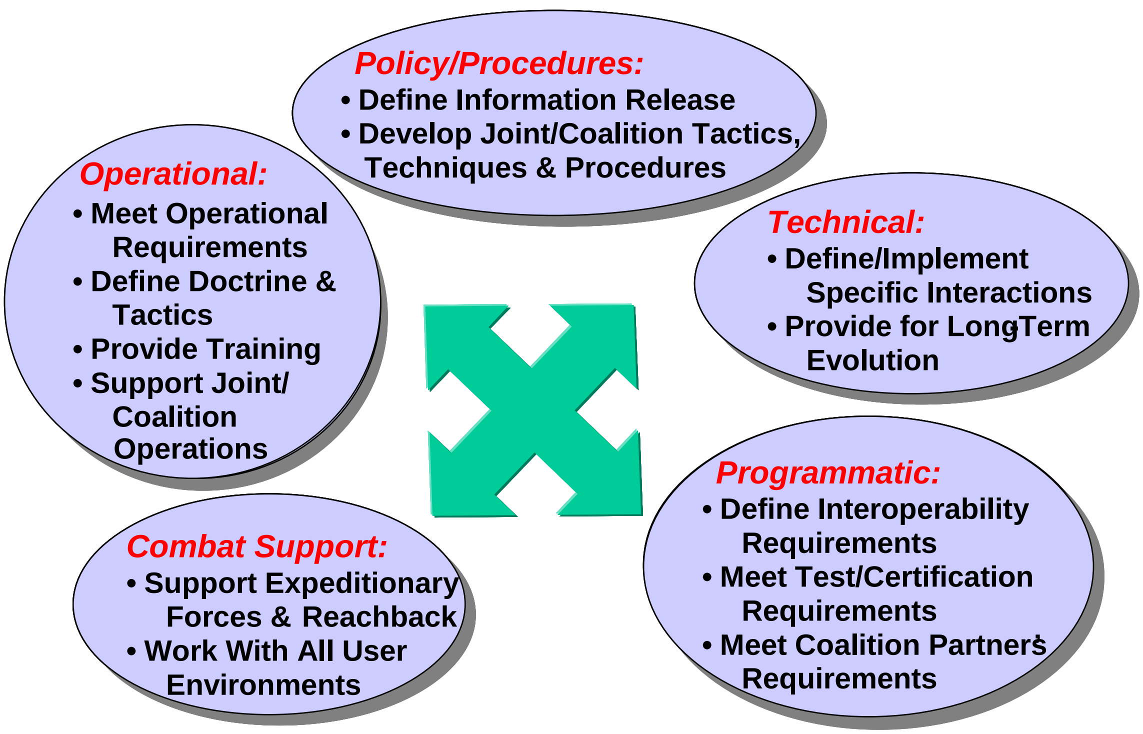


Figure 3-2. *Interoperability Has Many Dimensions*

The diversity of factors that must be harmonized to achieve interoperability is suggested in Figure 3-2. In joint or coalition operations, consistent policies and procedures that enable sharing and use of information across national and Service boundaries are essential. For each

organization and system, interoperability raises a wide range of operational and support questions. Finally, in requirements definition and acquisition processes, interoperability generates both technical and programmatic concerns. This last aspect is especially troublesome, because interoperability is quintessentially a force or system-of-systems proposition, but our approach to providing systems focuses on individual programs. Historically program managers (PMs) have great difficulty compromising their narrow individual interests for the sake of the greater good. Conversely, the individual PM is increasingly seen as being responsible to make interoperability happen, yet the largest part of the problem lies in the implementation of other systems and is thus beyond the PM's control. Many of the items listed in Figure 3-2 are further explored in this and other chapters of this report.

These issues are not new. The Department of Defense (DoD) has pursued endless standardization initiatives in equipment and procedures. The North Atlantic Treaty Organization (NATO) has for decades described rationalization, standardization, and interoperability as a high alliance priority. And the impressive record of military successes by the United States and our allies since Vietnam attests that these efforts have not been without effect. Today's joint and coalition forces stand without peer in the global security environment and are superbly capable, especially in large-scale conflicts. However, two things are different going forward in the 21st century. One is the exponential growth in our reliance on information in operations, creating both a host of new and more complex interoperability challenges and an ever-greater need to deal with them. The other is the reality that missions at the low end of the conflict scale—humanitarian relief, evacuations, separation of hostile parties, and the like—will be the most frequent taskings of our military forces. The situational ambiguity, lack of clear separation among hostiles and neutrals, limits on use of weapons, and other factors in such situations place extreme demands on enabling information processes and interoperability.

As the first step in dealing with the interoperability problem, it is essential that the meaning of the term and its many facets and implications be clearly understood. Like many other words (architecture comes to mind), *interoperability* means different things to various individuals and organizations

- To communicators, *interoperability* usually means the ability to connect nodes and exchange messages. The key to this dimension of interoperability is a set of well-defined interfaces across which interacting information processes can talk to each other.
- To information technologists, it usually means the ability to connect equipment via networks and to have software applications that cohabitate and (ideally) cooperate when loaded on workstations, servers, and nets. The key here is control of the platforms on which applications ride, of the shared services they use, and of the networks through which they exchange data.
- To the warfighter, whose opinion is the one that counts, interoperability means something much closer to the definition given earlier: the ability to exchange information in such a fashion that it enables cooperative activities to accomplish the mission. This requires that *all* aspects of interoperability be accounted for.

We have found that the best approach to shed light on this complexity is to construct a hierarchy of successively higher levels of interoperability. Figure 3-3 summarizes this construct.

- At the lowest level, interaction requires that the parties involved share channels for communication. These may be landlines, voice radios, data links, satellite communications, or, for that matter, couriers on horseback. This layer is labeled "Connectivity" in the figure, and it is

characterized by the physical and electronic parameters of a channel; an example would be the waveform (frequency, modulation, power level, etc.) of a network radio. Connectivity enables the exchange of *signals* via *data links or channels*.

- Next, we require compatibility in the way these channels are used to exchange messages. For a voice radio, this can be as simple as a common language and a set of defined terms. In current DoD directives,[4] data exchanges are specified by information exchange requirement (IER) matrices, which specify transactions among specific platforms and operational facilities in response to particular events. For a network or data link, messaging is controlled by a protocol that governs such things as the message structure, how data is encoded, how errors are detected and corrected, and how networks and channels are managed. A typical example is the network protocol and J-series messages defined for Link-16. We call this layer "Communication," and it enables the exchange of *messages* to achieve *shared data*.
- At the next level up, the issue becomes one of compatible information processes that ensure that shared data is treated and used consistently. At this point, a common information model, discussed in detail later, is absolutely essential. Aspects of this would typically include use of appropriate elements of a common operating picture (COP) via shared databases and use of the same or equivalent algorithms for data processing. We call this layer "Information Exchange," and it results in *shared information* among the participating information systems.

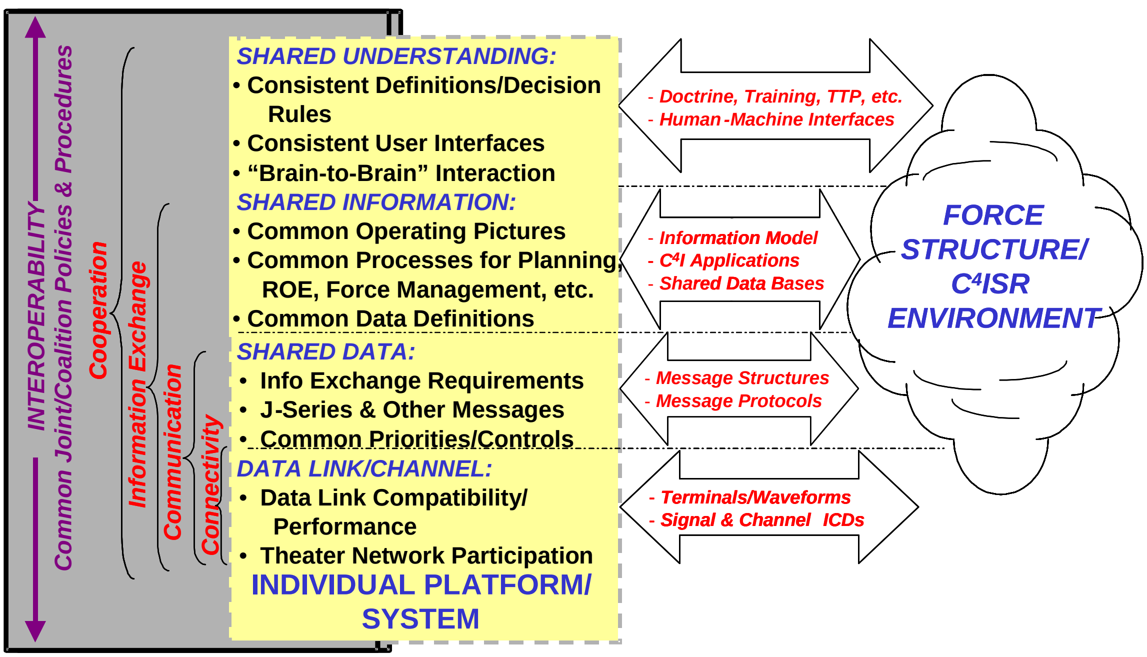


Figure 3-3. *A Hierarchy of Levels of Interoperability Illustrates Its Complexity*

- Yet another set of interoperability factors enters when we address the top layer, involving the interaction between information systems and human users. This involves both the human-machine interface, especially the need for consistent information presentation, and the underlying cognitive processes involved in decision rules, tactics, and training. When this level is fully

[4] Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 6212.01B, "Interoperability Supportability of National Security Systems, and Information Technology Systems," May 2000.

achieved, the result is what has been called "brain-to-brain" interoperability[5] such that commanders and warfighters possess the common understanding that enables cooperative action. Accordingly, we call this layer "Cooperation" and characterize it in terms of *shared understanding*.

- Finally, true joint and coalition interoperability demands a foundation of common policies and procedures, drawn in the figure as a background factor spanning the whole interoperability hierarchy. This goes beyond considerations of compatible equipment and equivalent tactics and training. It involves political issues of information release among nations, unity of command for coalition forces, and shared understanding of legal constraints and rules of engagement. With this, we have the kind of *interoperability* that modern warfare requires.

There may be situations in which levels of interoperability in Figure 3-3 can be achieved despite failures or deficiencies in the layers below. In general, however, robust and reliable interoperability is best achieved through systematic attention to building each level on a solid foundation of the preceding levels, solving problems a layer at a time and ensuring that all aspects of the problem are addressed in due sequence.

3.3.2 Typical Interoperability Problems

To make the somewhat abstract discussion of the introductory section more concrete, we have compiled a few real-world examples. Lessons learned from Operation Allied Force[6] and other recent operations, exercises, and experiments illustrate the kinds of non-interoperability with which this chapter is concerned. Some problems are susceptible of relatively near-term and inexpensive fixes, while others will require anything from system acquisitions and modifications to resolution of national information policy issues. A few representative problem areas are listed below to give a sense of the situation, along with some candidate near-term actions to address them. More pervasive, longer-term approaches are addressed in later sections of this chapter.

- **Inadequate Secure Communications.** The coalition force operating in Kosovo found that secure communications were sometimes not adequate, in part due to the greater level of technical sophistication of U.S. systems. *Near-term fix:* Work with allies to deploy additional secure radio frequency (RF) and landline communications assets, including attention to a coalition encrypted Link-16 capability.
- **Separate U.S./Coalition C^2 Networks.** Policy issues affecting information sharing with allies caused a number of problems. NATO secure networks proved incapable of handling heavy traffic such as the air tasking order (ATO) until a work-around involving a scheme to tunnel the traffic through other secure channels was devised. Similarly, separate U.S.-only and coalition ATOs were required, which created additional work and slowed dissemination of C^2. *Near-term fix:* Resolve information release policy issues and publish a single ATO, with a U.S.-only annex if required for specific content. Work with allies to deploy higher capacity secure networks and to implement guards and other measures as required to allow connectivity.
- **Inadequate Management of Network Bandwidth and Spectrum.** Central coalition management of limited network capacity and spectrum allocations continued to be a problem, as in earlier operations. Multiple approvals, each taking time, were required to use needed frequencies. *Near-term fix:* Develop and implement improved tools and procedures, including

[5] Julian Ranger, *Through Life Interoperability Program (TULIP) Handbook*, STASYS, Ltd., 1999.
[6] *Initial Report: the Air War over Serbia, Aerospace Power in Operation Allied Force*, United States Air Forces in Europe, Studies and Analysis Directorate, April 2000.

use of available systems for monitoring and managing Link-16 and other key data links, and pre-coordination of spectrum allocation with host nations.

- **Incompatible U.S./Coalition Systems in the Coalition Air Operations Center (CAOC).** The U.S. employs the Contingency Theater Air Planning System, and is moving toward the even more sophisticated Theater Battle Management Core System (TBMCS), while NATO uses different systems with a number of incompatibilities. This hindered coordination among coalition forces. *Near-term fix:* Work with allies to establish better collaboration tools and procedures, including automated translation of files and messages to bridge system incompatibilities, and use exercises to better define problems and identify solutions.
- **Incompatible Procedures for the Same Aircraft or Weapons.** In some cases, air forces employing the same systems had evolved different tactics and procedures, complicating cooperative operations. *Near-term fix:* Use joint and coalition exercises, training and operations to develop common tactics, techniques, and procedures (TTPs).
- **Multiple Specific Disconnects.** A number of specific problems have been identified, including inconsistent time references for Link-16 messages, inconsistent callouts from identification systems, limited interoperability of ground force and aircraft radios, and many others. *Near-term fix:* Case by case basis, clearly define the problem and seek affordable (especially through procedure changes) corrective actions.

3.3.3 Interoperability and the Expeditionary Aerospace Force (EAF)

The Air Force is well along in transitioning to the EAF and now plans to go to war using Aerospace Expeditionary Forces (AEF). This concept of operations (CONOPS), when fully developed, calls for the Air Force to deploy a precisely tailored force, including the required communications, in as little as 24 to 48 hours to meet national requirements. This poses enormous interoperability challenges. Training and maintenance are still done by Numbered Air Forces (NAFs) using procedures that are often peculiar to a particular theater, while the AEF that goes to war is likely to consist of units chosen from various NAFs. It is vital that the various units of an AEF be interoperable, including all aspects addressed in Section 8.1, in order to be ready to generate sorties and operate as a cohesive force immediately upon arrival in theater. It would be highly desirable as part of the work-up to an AEF's window of vulnerability for deployment to ensure that the information systems, TTPs, support systems, and other essential assets are fully compatible. In the long term, the JBI construct greatly simplifies this problem, but the Air Force requires a near-term solution as well.

The Navy faced a similar problem in dealing with the ships that form a battle group and found that they sometimes went to sea with incompatible systems. To solve this problem, the Navy developed the Distributed Engineering Plant (DEP), a network of simulation facilities to test the interoperability of the systems installed on the ships, with the software load that is heading for sea, before the battle group sails. We recognize that the AEF problem differs, primarily because the AEF has a more flexible schedule. The Navy battle group's composition and departure date are known well in advance. The AEF may be dynamically configured on 24 hours' notice. However, there is a rough equivalent in the 3-month deployment vulnerability window through which the AEFs rotate. Interoperability of like wings within the AEF is tested during the 6-month Normal Operations Phase II. The AOC, lead wings, assigned wings and squadrons, and the associated lead mobility wings should be tested in a DEP-like facility before beginning the 6-week schedule of exercises in the work-up phase. This facility should also simulate standing AOCs, with which the AEF will most likely operate. This will enable the exercises to be used to

train the people and check out the procedures, rather than to verify the interoperability of the equipment. A DEP-like facility should also simulate low-density, high-demand assets for interoperability tests. Ideally, such a facility would also simulate the elements of other services with which the AEF will most likely interact. In our recommendations, we offer a specific approach to achieve this through a "Distributed C^4ISR Simulation Network."

AEF interoperability extends to more than Air Force airplanes and command centers. Long-haul communication for reachback to home theaters is likely to require that communications assets deploy even before combat forces. Depending on the level of development of the countries and bases hosting the AEF, this may entail considerable equipment and require interoperability with a wide variety of space and terrestrial communications infrastructure. Ideally, both routine training and preparation for an actual deployment should include work with joint and coalition forces likely to be involved.

The Office of the Secretary of Defense, Under Secretary for Acquisition and Technology and the Joint Staff J-8 have established a program to develop a Joint Distributed Engineering Plant (JDEP), but that program has been underfunded. The joint group has also begun to explore the Joint Theater Air and Missile Defense mission. The Air Force should either create a Program Objective Memorandum (POM) for the JDEP and ensure that it meets the needs of the EAF, or develop an Air Force facility like the Distributed C^4ISR Simulation Network to meet the needs of the AEFs and plan to eventually tie it to the JDEP. Facilities that would be candidates for integration into a JDEP network include those of the C^2TIG, the ESC C^2 Unified Battlespace Environment (CUBE) and the Theater Air C^2 Support Facility (TACCSF), as well as new facilities like the proposed experimental C^2 centers at Langley and Nellis AFBs.

3.3.4 Joint and Coalition Interoperability

Following the Panel Charter, we have devoted considerable attention to the subject of joint and coalition interoperability. In addition to the discussion below, Section 2.6.9 of the Concept and System Definition Panel Report in the previous chapter highlights some of today's most critical operational interoperability problems. The primary focus of this study is on Air Force problems, processes and systems, with a goal of having the Air Force "linked by 2005." However, almost any foreseeable combat operation, and many humanitarian and peacekeeping missions, will involve joint or coalition forces. Thus, while the C^2 interoperability challenge within the Air Force alone is significant, the effort must clearly be extended to the total ensemble of forces involved in an operation. It's difficult to imagine a scenario where the operational limitations created by a lack of interoperability, as we know them today, can be solved by even perfect Air Force interoperability. The task of achieving an interoperable joint or coalition force is daunting and has proved intractable; it impacts everything from doctrine and national policy to systems, processes, procedures, and missions. Success in coalition operations will often yield important political and diplomatic benefits and may be essential due to the need for an international mandate and for geographic access.

3.3.4.1 A Problem with Many Dimensions

Interoperability in general, but especially in the context of joint and coalition operations, is impacted by virtually every aspect of the forces involved, including

- **The Operational Dimension:** policy and doctrine, training, the requirements process, and rules for the conduct of joint and coalition operations
- **The Technical Dimension:** performance capabilities of various systems, conformity to interface standards and common procedures, information assurance, and overall levels of technical sophistication of participating forces
- **The Programmatic Dimension:** specification and fielding of interoperable systems, interoperability testing and certification, and resolution of interoperability issues involving multiple systems and agencies
- **The Support Dimension:** compatibility of weapon systems and multiple support environments, especially under deployed and austere conditions

As summarized in Section 3.3.2, recent contingencies, as well as tests, exercises, and experiments, have uncovered deficiencies and illustrated the consequences of joint or coalition interoperability shortfalls. To choose one example among many, ambiguous “identification, friend, foe, or neutral” declarations, as were identified in a 1994 Link-16 test at Mountain Home AFB, can have a debilitating impact on rules of engagement (ROE) and the success of the air war. When System “A” can flag targets as “friendly,” “presumed friendly,” “unknown,” “presumed hostile,” and “hostile,” and System “B” has only “friendly,” “unknown,” and “hostile,” then system “A” displays “presumed friendly” as “unknown.” At a minimum, the result is confusion in what should be a simple task of handling a common track. More seriously, it’s easy to envision this situation leading to fratricide or to a friendly aircraft’s being surprised by a hostile. In another case, lessons learned from the Kosovo operation show that various Link-16 terminals that comply with the applicable Standardization Agreement nevertheless had incompatibilities that prevented correct information exchange due to such problems as inconsistent definitions of the time stamp incorporated in a report. The overall message is that interoperability problems are numerous, often subtle, and frequently difficult to diagnose and correct.

It’s difficult to set the right boundaries on interoperability requirements, largely because it’s impossible to predict the next fight. Which forces from which Services and nations will participate in which roles are matters unlikely to be settled until after a crisis erupts. Moreover, the need for interoperability increasingly extends to non-Defense government entities (such as the Department of State, Coast Guard, and Department of Transportation) and even to non-government organizations (NGOs), especially in humanitarian missions. A prime requirement is thus that joint and coalition interoperability be general and robust, not requiring the kind of *ad hoc* work-arounds that have been used to patch disconnects in recent engagements and not assuming that any single country or Service has sole responsibility to correct interoperability problems. Platforms should be able to communicate, command centers should be able to exchange classified information, and commanders should have a shared and consistent view of the situation, regardless of which systems are in use or who provides them. Today, the U.S. armed forces and their allies are far from that ideal.

Difficulties in interoperability with coalition partners become evident every time we operate together or conduct a joint or combined exercise. We learn the lessons over and over, yet too

often seem unable to acquire systems, develop TTPs, establish compatible support environments, and conduct training so as to achieve the required level of interoperability. To take a simple but suggestive example, when something as basic as a secure telephone is procured as a NOFORN (U.S.-only) system, an obvious and powerful instrument of interoperability is frustrated.

This is not to ignore the reality that some information, and even some technology and systems, will not be shareable with our allies. But such decisions must be balanced against the overarching need for interoperability, and effective means to command, control and support a joint or coalition force must be assured. To return to the CAOC example cited earlier from Operation Allied Force, where we were operating with primarily NATO allies (when the United States decides to release sensitive information, it's safe to say that NATO countries get it first), we found the need to restrict ATO information on selected systems. The Joint Force Air Component Commander (JFACC), Lt Gen Michael Short, needed as always, to get the tasking, Airspace Control Order (ACO), Special Instructions, and other C^2 information to all the forces in the coalition. He later said that there was nothing that could not have been handled by a U.S.-only cell within the CAOC, and that we should never again publish separate ATOs. Information exchanges that cross boundaries between differing levels of classification will be a continuing challenge, but a combination of technical, procedural, and policy measures must be employed to simultaneously ensure information security and provide timely and robust interaction within the elements of the force.

Information release is essentially a policy issue, but its resolution needs to be complemented by technical solutions that ensure that coalition secure systems have adequate capacity and that measures such as software guards to isolate computing environments at different levels of classification are used when appropriate. The key to success is to develop C^2 systems that are flexible enough to interface with other agencies and able to protect classified information in such interactions, together with information release rules and procedures that account for the operational realities of employing joint and coalition forces. Such a strategy can only succeed if it is rooted in an architecture that establishes the information structure to which the elements of a joint/coalition force must conform and the interfaces across which information is exchanged. Much of the remainder of this chapter is devoted to various facets of C^2 architecture and its implementation.

There are additional constraints on achieving joint or coalition interoperability that are inherent in the way the United States and its allies acquire systems. Some can be overcome, and some probably cannot. First, and perhaps foremost, is the system-centric approach to acquisition. Historically, the focus in all Services has been to get the operational capability of a system fielded with little or no regard for interoperability with the rest of the force. Interoperability has not, until quite recently, been a key performance parameter (KPP). Legacy systems present a bewildering array of interfaces, and often require gateways to allow information exchange. Force-level architecture has consisted of little more than a catalog of standards, and competitive pressures have given industry an incentive to deliver closed, proprietary systems. Technology transfer issues and additional proprietary issues relating to foreign industry hinder coalition interoperability solutions. Compliance mechanisms for interoperability with enforcement power from the requirements definition stage through production and delivery of systems have been lacking. Cost is often cited as a rationale to compromise interoperability because there is no way to account for economic impacts at any level other than an individual system or program. In short, the entire system development process conspires against interoperability.

3.3.4.2 Interoperability Initiatives

Even so, some recent initiatives offer hope. DoD has developed a C^4ISR Architecture Framework[7] that establishes the construct of operational, technical, and system views of an architecture, which may apply to a system, a family of systems or a system of systems (Figure 3-4). Each view is defined by a set of mandatory and optional products. The framework also provides common definitions, and common references (building blocks), for example, the Uniform Joint Task List, Shared Data Environment, Technical Reference Model, Joint Technical Architecture, and the Defense Data Dictionary System. The framework provides a basis for attacking the architecture problems described above. The Joint Staff is drafting a Joint Operational Architecture (JOA), supported by a set of Joint Mission Architectures (JMAs). If carefully developed and rigorously applied, these may be important elements in a broad interoperability strategy, initially for U.S. forces and potentially with allies.

DoD policy has established interoperability as a KPP, and CJCSI 6212.01B spells out the process, roles and responsibilities of the Defense Information Systems Agency (DISA), especially the Joint Interoperability Test Center (JITC), the Joint Staff, and the Services in achieving interoperability certification for new systems. The instruction places heavy emphasis on proper treatment of interoperability in requirements definition and on the application of the C^4ISR Architecture Framework. The approach is centered on the definition of a set of critical, top-level IERs, and the limitations of this view of interoperability are discussed in a later section of this chapter.

DoD's grand strategy for achieving Information Dominance is the Global Information Grid (GIG)—the overall Defense Transformation Initiative aimed at providing the information infrastructure required by U.S. forces in the 21st century. It responds to the Clinger- Cohen Act of 1996, to various mandates for Defense reform, and to the concept of Information Dominance in *Joint Vision 2010 and Joint Vision 2020 (JV2010 and JV2020).* The JOA is being defined as the Operational Architecture View of the GIG. The Deputy Secretary of Defense recently issued a GIG Guidance and Policy Memorandum.[8] This directive provides for the GIG "as a cornerstone in" DoD's "Revolution in Military Affairs, the Revolution in Business Affairs, and in enabling the achievement of Information Superiority." A GIG Capstone Requirements Document (CRD) has been drafted by U.S. Joint Forces Command. The GIG is defined as "the globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating and managing information on demand to warfighters policy makers and support personnel." Both an overall vision and a GIG Systems Reference Model have been developed.

---

[7] *DoD C^4ISR Architecture Framework, Version 2*, 18 Dec 1997.

[8] DoD CIO Guidance and Policy Memorandum 8-8001, March 31, 2000—Global Information Grid.

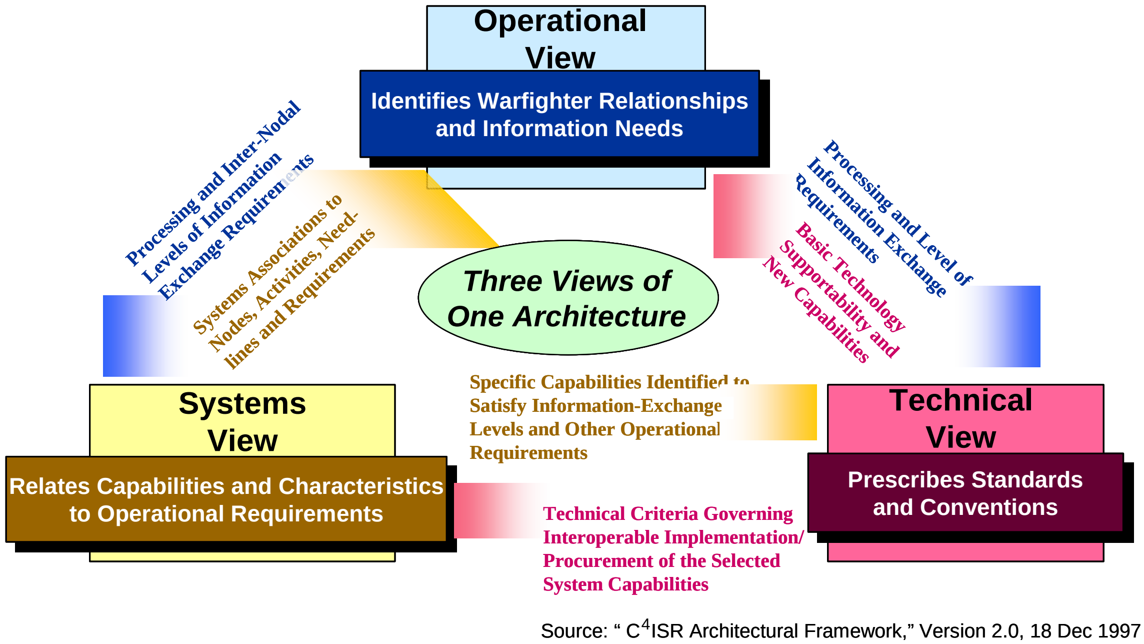


Figure 3-4. *Three Views That Define an Architecture*

OASD/C³I has been designated DoD's Chief Information Officer (CIO), and CIOs have also been designated for the Services, Unified Commands, and major Defense Agencies. A CIO Executive Board was also mandated by the Act. Under Title 10 U.S. Code, Section 2223, as amended by Clinger-Cohen, the DoD CIO has statutory authority to make and approve IT budget requests, ensure IT interoperability, ensure application of standards, and eliminate duplication. Overall, the DoD CIO community may provide an important forum and mechanism for attacking the problems that have bedeviled joint interoperability. OASD/C³I is revising the applicable policy documents and has under way a wide variety of activities aimed at various aspects of interoperability. JITC has extensive experience in working interoperability problems, possesses valuable facilities for testing, and has taken a proactive stance in working with programs to address interoperability requirements. A less formal but nonetheless effective forum for working interoperability issues has been formed by the concerned PEOs of the three Services.

Today, the GIG is conceptual, but as it is implemented in operational architectures, acquisition programs, and other concrete measures affecting DoD information systems, it may help to provide the "big picture" within which legacy stovepiped systems can move toward the required levels of integration and interoperability. The scope and purpose of the GIG substantially overlap those of the JBI (Chapter 8), and it seems likely that the JBI, which is better defined and more in tune with modern technology than the GIG, will supplant it over time.

Finding affordable ways to improve the interoperability of legacy systems, as well as overcoming inertia and parochialism within Services and their programs, remain as challenges. However, interoperability is receiving unprecedented attention, and the creation of the KPP provides a badly needed incentive for individual PMs to treat interoperability with the priority it deserves.

3.3.4.3 Air Force–Army Interoperability Issues

Close linkage between air and ground forces is obviously essential to mission success and fratricide prevention. Both C^2 centers and individual units and platforms are involved. The Army Battle Command System (ABCS) in a Tactical Operations Center must interact closely with the TBMCS in an AOC. Currently, coordination is accomplished through a collocated Battlefield Coordination Detachment (BCD) in the AOC, and Army deep operations planning and execution require timely information exchanges among the Deep Operations Coordination Center (DOCC), the AOC (through the BCD) and the Air Support Operations Center (ASOC). Progress has been made, but a number of interoperability issues remain.

ABCS components that require interoperability in various forms with the Air Force C^2 environment include

- **Global C^2 System–Army (GCCS-A):** GCCS-A is the Army component of the GCCS initiative. It provides automated C^2 tools to enhance warfighter capabilities during joint and combined operations.
- **Maneuver Control System (MCS):** MCS is the battle command system for the maneuver commander and operational staffs. It provides the common tactical picture, planning aids and battle tracking and execution capabilities. Its products include friendly unit locations, operational plans, and other operational data essential for battlespace awareness.
- **Advanced Field Artillery Tactical Data System (AFATDS):** AFATDS is the fire support component of the ABCS. It provides tools for planning, coordination and control of fire support assets.
- **All Source Analysis System (ASAS):** ASAS is the intelligence electronic warfare element of ABCS. It is the primary intelligence tool at battalion through corps levels to fuse multi-source information into a single threat picture. It compiles intelligence information into databases that support intelligence preparation of the battlefield (IPB), situational awareness, and target nomination.
- **Tactical Airspace Integration System (TAIS):** TAIS is an information management system that supports Army Airspace C^2 at corps, divisions, and BCD.
- **Automated Deep Operations Coordination System (ADOCS):** The Army has developed ADOCS as a management tool to coordinate deep operations. ADOCS enables accelerated mission planning and airspace coordination. It could be integrated with the ATO databases. ADOCS is interoperable with GCCS, GCCS-A, AFATDS, ASAS, and ADA. Third Army (Army Forces Central Command) is evaluating its potential to support joint warfighting.
- **Air Mission Planning System (AMPS):** AMPS provides a capability to rapidly transmit Army aviation air routes and other functions to TAIS. The ground liaison officer and the suppression of enemy air defenses (SEAD) squadron can use it to see the Army aviation air routes and changes that may be made to them while helicopters are en route.

The Air Force TBMCS and Army Project Managers for GCCS-A, ASAS, AFATDS, and the Air Missile Defense Work Station (AMDWS) signed an Interface Control Document (ICD) in 1998. Below is a summary of the situation:

- **TBMCS—GCCS-A:** The ICD calls for interfacing via exchange of U.S. Message Transmission Format (USMTF) messages. The current plan is to use the 2000 version of USMTF. GCCS-A interfaces with TBMCS to provide target nomination. The ATO and ACO are provided from TBMCS to GCCS-A.

- **TBMCS—MCS:** The MCS contract specifications include a requirement for MCS interface with TBMCS. Specifics of how this interface will occur need resolution.
- **TBMCS—AFATDS:** AFATDS interfaces with TBMCS at the AOC and the ASOC. The interchange will be via USMTF or USMTF-like messages. This issue is assessed as yellow, turning green when TBMCS is fully developed and fielded.
- **TBMCS—ASAS:** ASAS interfaces with TBMCS at the AOC. ASAS will exchange intelligence information through the Modernized Integrated Database (MIDB) upon completion of ASAS 6.2 in September 2000. Should this approach not work, there needs to be a direct interface to support en route aircraft retasking.
- **TBMCS—AMDWS:** TBMCS will exchange data with a single designated AMDWS. The designated AMDWS will further distribute the ATO and ACO.
- **TBMCS—TAIS:** These systems are not interoperable. TAIS has demonstrated that it can exchange USMTF ATO and ACO messages with TBMCS. The PM for Air Traffic Control acknowledges the requirement for TAIS to be interoperable with TBMCS. TAIS is implementing the Joint Common Data Base and should then be interoperable.

Specific issues that need attention include

- Disconnects between TBMCS and ABCS that inhibit dynamic targeting and real-time force coordination must be resolved. If the GCCS vision of a real-time COP, or Family of Integrated Operational Pictures (FIOP), is realized, it will support database-to-database interactions and help ensure consistent, timely views of the battlespace by both air and land commanders. An important aspect of this is timely exchange of intelligence information; an example would be use of ASAS feeds in the AOC process for IPB. Another is the need for current, accurate friendly force locations in the situational awareness picture in the AOC and in Air Force cockpits.
- Better means are needed for dynamic tasking and cross-cueing of Air Force and Army intelligence, surveillance and reconnaissance (ISR) assets to locate and identify targets. For example, the AOC collection manager should have a data link to the DOCC to nominate targets and allow cross-cueing of Army ISR assets (for example, GUARDRAIL Common Sensors and Fire Finder radars). Likewise, the DOCC should have a data link to the AOC for tasking Air Force assets. Procedures should support dynamic retasking of collection assets to support real-time targeting.
- The ATO process and timeline need to better support Army flight operations. The Air Force, Navy, and Marine Corps control aircraft operations by tail number. In contrast, Army aviation assets are controlled by unit assignments. The current 72-hour ATO cycle is too long and inflexible to accommodate Army flight operations. In addition preplanned, deliberate Army flying missions that cross the forward line of troops (FLOT), including deep attack and air assault missions should be in the ATO to ensure search and rescue and SEAD support. Better deconfliction of airspace and missions is another important consideration.
- The AOC needs better means to initiate and control attack of mobile targets. Currently, Desired Mean Points of Impact (DMPIs) are required to put a target on the draft Joint Integrated Prioritized Target List and Target Nomination List. Mobile targets do not have DMPIs in a prepared database like fixed targets do in the MIDB. Currently, in exercises, the BCD must create DMPIs for mobile nominations, which is a time-consuming process. It will be impossible to add DMPIs in a real-world situation where the ground forces may nominate dozens of targets.
- AFATDS interoperability with TBMCS at both the AOC and the ASOC is essential for integrating battle plans and coordinating situational awareness. Air Force and Army plans call for TBMCS—AFATDS interoperability via eight different USMTFs that focus on targeting and friendly unit information. AFATDS should be able to dynamically retask assets to facilitate the

attack of time-critical targets. By implication, close coordination between ABCS systems and the Battle Command Center of the next-generation Air Force C^2 structure will be essential.

- Close air support (CAS) forces must have improved situational awareness to understand the dynamics of mobile ground operations. A key deficiency in air-to-ground operations is that ground forces are not visible in the Joint Data Network (JDN)—the joint tactical data link that enables all participants in a theater air defense organization to create the single integrated air picture, manage air and maritime battlespace, and conduct identification—friend or foe. One approach might be a gateway between the Army Enhanced Position Location Reporting System/Variable Message Format (VMF) ground network and the JDN so that CAS aircraft can have a more accurate location of friendly ground forces to reduce fratricide and allow more accurate air strikes in proximity to the FLOT.

3.3.4.4 Air Force-Navy Interoperability Issues

The Navy and Air Force have fewer issues with fratricide and coordination of flying and surface forces, but important interoperability matters nevertheless require attention. In some scenarios, a "JFACC Afloat" will run the air war, at least in its early stages, from a Fleet Command Ship such as the USS Coronado, and assigned Air Force units must be prepared to operate with such an AOC. Naval aviation must be able to receive the ATO and smoothly feed tasking into its mission planning systems. Dynamic control of operations, retasking of aircraft in flight, coordination of strikes on time-critical targets, and combat search and rescue are just a few of the areas where high levels of interoperability are critical.

In future coalition operations, the Air Force is likely to operate with allied navies. Examples of potential allied contributions, the first three of which could entail interoperability with Air Force aircraft, include

- Development of new guided missile anti-air warfare frigates with state-of-the-art 3D radars and longer-range surface-to-air missiles (France, Germany, Italy, Spain, and UK)
- Development of new amphibious warfare ships (Italy, Spain, and UK)
- Ships for surface surveillance (multiple nations)
- Continued proficiency in the key niche area of mine countermeasures (France, Germany, Netherlands, and Spain)

The following Navy systems must interoperate with Air Force C^4ISR systems, tallied in rough order of importance:

- **Joint Tactical Information Distribution System (JTIDS)–VMF.** Air Force and Naval Air cannot work together without Link-16. The greatest challenge is to get the message formats into each airplane as needed to accomplish the mission. The Navy and the Air Force use different message formats to pass data and information, often resulting in incompatibility. Other data links (Situation Awareness Data Link [SADL], Information Dissemination Management [IDM], etc.) may also present issues.
- **GCCS-Maritime (GCCS-M).** This will be an essential provider of data to the COP/FIOP for all users, including the Air Force.
- **Global Combat Support System-M (sometimes known as the Navy Tactical Command Support System).** Compatibility is essential to joint logistics planning and execution.
- **AEGIS.** This is an essential participant in mutual support among all services in the littoral battlespace for both air-air and theater ballistic missile defense operations.

- **Joint Mission Planning System (JMPS).** This is intended to be a joint system that *ensures* compatible mission planning; there could be issues if Service-specific solutions are employed.
- **JSIPS–N, including the Tactical Input Segment.** Compatibility is essential for joint support with tactical imagery.
- **Cooperative Engagement Capability (CEC).** This could become the basis for the Joint Composite Tracking Network (JCTN), and will be a major element in joint air defense operations in the littoral.
- **Advanced Combat Direction System.** This is being implemented on attack carriers, but is currently not even interoperable with AEGIS, let alone Air Force systems.
- **Joint Tactical Radio System (JTRS).** This and other common tactical radios will be critical in joint operations.
- **TALON Gateway.** This Air Force Tactical Exploitation of National Capabilities Program (TENCAP) initiative is to put a "translator" onto a widebody aircraft to send and receive ultrahigh frequency over-the-horizon information, translate it into the proper format (Link-16, SADL, and IDM), then retransmit the data or imagery to the appropriate fighter aircraft. This system could be the model for future efforts to "unstovepipe" systems.
- **Airborne Broadcast Information.** This effort, sponsored by Air Mobility Command (AMC), is a direct descendant of the Multi-Source Tactical System developed by Air Force TENCAP. AMC is purchasing many of these systems for its aircraft to give them enhanced situational awareness; interoperability with supported Navy units would be valuable.
- **Radiant Topaz.** This is a Surveillance, Reconnaissance, Management Tool for collection management.
- **Multilevel Security (MLS).** In general, a robust joint solution to the MLS challenge is a major issue.
- **Meteorology and Oceanography (METOC).** The Navy has a very robust system here that could help meet the needs of the other Services.

3.3.4.5 Air Force-Coalition Interoperability Issues

Economic, doctrinal, and regional concerns intervene to inhibit interoperability between the United States and its allies. Many of our partners in NATO and elsewhere understand that they cannot reach parity with the United States in levels of C^4ISR investment. Especially when the United States does not have a robust and proven CONOPS for information-enabled operations in place, allies facing resource constraints and competing priorities can conclude that interoperability is not achievable. In addition, allies face difficult decisions between buying U.S. systems as a route to interoperability and supporting their own or their neighbors' industries; issues of workshare and releasability of information and technology are crucial in this context. The United States has not always been sufficiently proactive in bringing allies into system requirements definition and program planning to allow time for mutually acceptable acquisition decisions to be worked out.

We can illustrate trends in C^4ISR that may contribute to interoperability problems in terms of the conventional three-level hierarchy of theater tactical networks as shown in Table 3-2.

Table 3-2. *Network Tiers in the U.S. C^4ISR Structure*

Network Tier	***Existing/Planned Systems***
Joint Planning Network (JPN)	• Defense wide-area networks (Non-Secure Internet Protocol Router Network/Secret Internet Protocol Router Network (SIPRNET), Joint Worldwide Intelligence Communications System, etc.) supporting GCCS, Joint Deployable Intelligence Support System, Defense Message System (DMS) • Secure voice and data, Global Broadcast System, video teleconferencing (VTC), etc. • Planning networks (for example, TBMCS)
JDN	• Tactical Data Links (Link-11, Link-16, etc.) • Theater and national data broadcasts (Tactical Data Distribution System, Tactical Information Broadcast Service, etc.) • Common high-band data link
JCTN	• Sensor and weapons networks • CEC, sensor-to-shooter subnets

The lowest tier of the table has the most timeliness and the most direct link between information and weapon employment. These networks connect information sources to the combat direction system of a ship, a tactical operations center, an aircraft mission computer, or a weapon guidance system. The middle tier provides cueing, situational awareness, and force coordination. The highest tier accommodates information exchange, coordination, planning, and contextual information. In general, the scope of network operations decreases and responsiveness increases in moving down the tiers. Using this construct, Table 3-3 highlights the present and near-term prospects for coalition interoperability.

Table 3-3. *Assessment of Coalition Network Interoperability*[9]

Network Tier	***System***	***Interoperability Assessment***
JPN	DMS, TCI/IP-based messaging	• No blanket access to SIPRNET • Information exchange between networks depends on coalition MLS solution
	GCCS	• Allies buying subsets; releasability of some segments is uncertain
	TBMCS	• Allies buying subsets; releasability of some segments is uncertain
	Secure Voice and VTC	• Issues with secure terminal equipment, Fortezza encryption cards, bandwidth limitations, etc.
	Intelligence systems	• Allies divided by access to secure networks
JDN	Data Links	Interoperability and data sharing likely to be extensive
JCTN	Sensor/weapons networks	Allied forces are likely to be excluded by U.S. policy and limited common system inventories

[9] R.R. Odell, P. Morley, K. Gause, and F. Ruiz-Ramon, *Toward a US Navy Strategy for C^4I Interoperability with Allies*, CAN Research Memorandum, 1999.

Overall, there are three reasons why problems with C^4ISR interoperability should be expected. First, the U.S. JPN will make the most intensive use of broadband satellite communications, creating an investment issue with our allies. Second, the proliferation of U.S. and other nations' networks will compound the interoperability challenge, especially in terms of achieving MLS solutions. Finally, U.S. advances in IT are likely to reinforce a U.S. preference for employing U.S.-only networks; access and information releasability will continue to be vexing problems.

The limited ability of allies to procure U.S. systems, for both resource constraint and industrial policy reasons, will be serious limiting factors. Interactions among the three tiers of Tables 3-2 and 3-3 are important. The increasing importance of information processes at the JPN level, the proliferation of networks, the limited releasability of certain key technologies, the wide spread in access to satellite communications bandwidth, and the limited availability of U.S. sensor-to-shooter chains to allies will limit the role their forces can play in major operations. U.S. forces will be in a superior position with respect to access to information and often will not know what access their allies have; allied access to U.S. networks is likely to continue to be unsatisfactory. Specifically:

- In coalition operations, U.S. armed forces are unlikely to change their C^4ISR suites for the sake of coalition interoperability, increasing the importance of linkages to allied networks such as the NATO CRONOS wide-area network.
- Allied access to U.S. networks will be restricted and variable. Some nations will have highly sensitive access, while others will not. Guards that allow connectivity between U.S. and allied networks in an MLS environment will be critical.
- Restrictions of the U.S. National Disclosure Policy are likely to be most restrictive at the level of the JPN.

As a result:

- Future coalitions will be stratified into groups of nations with various degrees of C^4ISR capability and interoperability with U.S. systems.
- C^4ISR interoperability is likely to be poor for the JPN and sensor-to-shooter chains.
- The task of diagnosing C^4ISR interoperability problems with allies and setting requirements will be scenario-dependent.
- U.S. responsibilities in coalition operations for information operations and protection could increase.

3.3.5 Critical Processes for Interoperability

Joint and coalition operations, especially in the emerging expeditionary force model, demand a level of interoperability that our existing methods of acquiring and employing systems are unlikely to satisfy. If interoperability is to be achieved, technical and operational solutions must be underpinned by a set of *processes* that can actually deliver the desired result. Among the most important of these are the processes governing

- Requirements analysis and definition for systems, systems of systems, and families of systems
- The definition, evolution, and application of architectures at these same three levels, including the choice and enforcement of standards
- The acquisition, testing, and long-term modification and upgrading of systems

- The development and implementation of joint and coalition doctrine, tactics, procedures, training, and exercises that make interoperability a routine and accepted fundamental of military operations

Unfortunately, the processes that prevail in these areas today are generally much more of a hindrance than a help. Process reform will be one of the most important, but also most difficult and time consuming, aspects of migrating our legacy forces and systems toward the vision of *JV2020*. Once again, the Internet and commercial practices have much to teach DoD. We seek an approach that can drive critical processes toward the broad goal of interoperability while balancing fiscal and operational priorities, minimizing the disruption of ongoing programs, and involving all interested parties, from policy setters to system developers to warfighters. Other panel reports concentrate on operational, acquisition, human factors, and technology processes for C^2. Here, we consider some aspects that are especially relevant to our area.

3.3.5.1 The Problem Today

In working on this study, we have repeatedly come up against the problems that result from a platform-centric view of military systems. Requirements definition, which is the bedrock to which the whole acquisition process is anchored, remains fixated on individual systems to meet specific operational needs, identified by narrow groups of users. There is little or no consideration of how synergy among the diverse elements of an integrated force might deliver more capability at less cost. Compounding the problem, DoD and the Services are only beginning to think about operational architectures and system-of-systems frameworks that might provide the kind of context requirements developers need in order to break out of this mindset. In short, what we have today is mostly a recipe for non-interoperable stovepipes. We pay a heavy price both in the kind of operational problems described earlier and in individual system costs driven up by the inability to use common solutions to common needs and the desire to optimize each system instead of the capabilities of the force to which the system contributes.

More recently, a great deal of emphasis has been placed on the infrastructure dimension; examples include the Defense Information Infrastructure Common Operating Environment (DII COE) as a way of standardizing information system platforms and Link-16 as the universal tactical data link. In the process, there has been a tendency in DoD to apply standardization mandates, sometimes before the thing being mandated was mature enough for real-world use. Our examination of the history of TBMCS suggests that a large part of its history of problems is due to the fact that it was committed to an early version of DII COE that lacked both the functionality and the stability to support it. In every case, the focus of interoperability initiatives has been on the lower levels of the hierarchy in Figure 3-3, especially on communications interoperability, when, in fact, many of the most difficult challenges lie at the higher levels.

3.3.5.2 Commercial Practice

The practice in the commercial world has rapidly evolved from one based on closed proprietary architectures with few broadly accepted standards to one of open, agreed-upon standards for most layers of the architecture. In addition to the technical lessons the private sector has to teach, we are interested in the processes used to achieve these results. Some of them are

- Individual companies see their financial interest in value-adding products that exploit a common infrastructure rather than in control of that infrastructure. This actually creates powerful

incentives to share information and agree to compromise on definition of standards so that the foundation on which competitive advantage is then erected can be put in place quickly.

- Standards activities are community based, and arise from communities of interest in specific domains such as banking, product engineering, and music. While standards committees are notoriously messy, time consuming, and contentious, they have an excellent track record in hammering out workable compromises in time to meet the needs of the participants.
- Standards are primarily oriented to interfaces and shared processes, rather than products, although the dynamics of the marketplace may create *de facto* standards around products like Microsoft Windows. The minimum set of standards that can ensure interoperability, both generally and within a specific domain, is all that will be developed. The outstanding example is the Internet protocol stack, especially Transmission Control Protocol/Internet Protocol (TCP/IP), and other effective standards have been widely used file formats (GIF, JPG, etc.) and popular application programming interfaces (APIs).

The evolution of the commercial marketplace from competing proprietary architectures (IBM, Burroughs, and others) to open architectures with interface standards, as described above, is instructive. Through the 1970s, computer manufacturers saw their financial interest in signing customers up to their proprietary architecture. With the development of the microcomputer, and the commercial development of DOS as a proprietary architecture with an open API, the market began to shift. Software developers began to develop a wide range of applications for the open API, and buyers wanted to be able to exploit this software. Competing proprietary architectures, even technically superior ones like the Macintosh, struggled in the marketplace because the users demanded access to the wide range of independently developed software. This process of standards extended to information exchange protocols such as hypertext markup language (HTML) and Structured Query Language. The process of opening the architecture is continuing; if current trends continue, the LINUX system, which has open source code as well as an open API, will overtake Windows NT as the most popular server system in 2001.[10] DoD lacks the discipline of the marketplace and must implement processes that provide the standards, the common services using them, and the incentive to choose them in specific systems over a set of slightly better optimized stovepiped solutions.

3.3.5.3 The Current DoD Interoperability Approach

IERs have become the fundamental basis for defining and assessing interoperability in DoD systems. CJCSI 6212.01B defines a process as summarized in Figure 3-5. The three key events are (1) certification that the relevant requirements document (Mission Need Statement, Operational Requirements Document, or CRD) adequately addresses interoperability; (2) certification that the interoperability requirements documented in the C^4I Support Plan (C^4ISP) via the IER matrix and set of system descriptions are supportable over the GIG; and (3) certification that the results of system test and evaluation prove that interoperability requirements are satisfied. Those IERs designated as “critical, top level” define an interoperability KPP that is a mandatory item for a decision to proceed at major acquisition milestones. They thus take on an importance far beyond engineering the interactions among systems.

[10] Briefing to the Summer Study by Walker White, ORACLE Corporation, 10 July 2000.

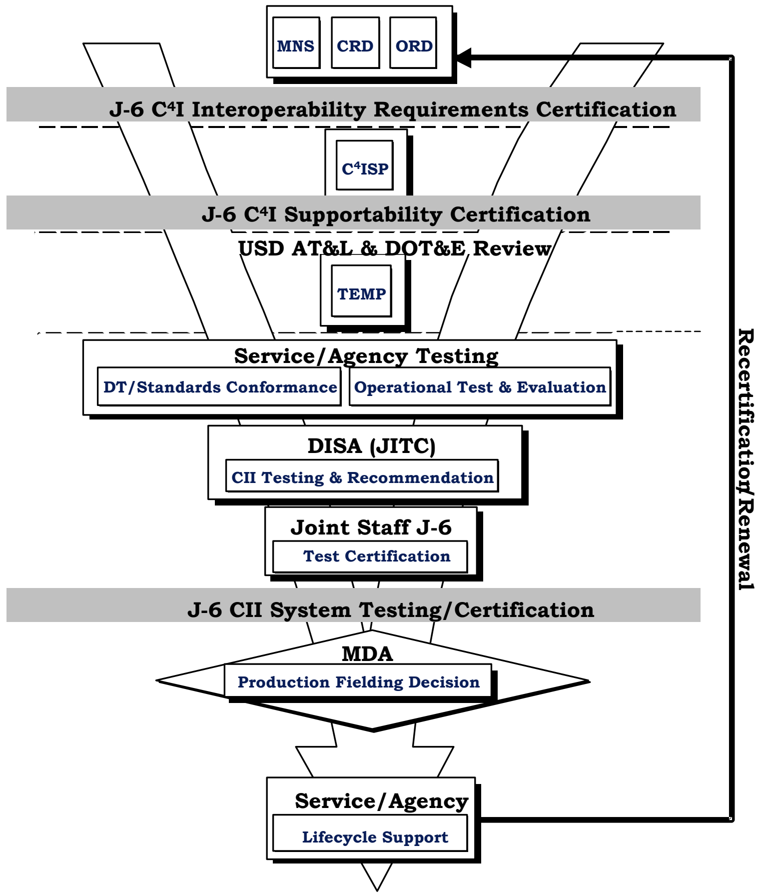


Figure 3-5. *CJCSI 6212.01B Establishes a Process for Assessing and Certifying the Interoperability of a Developmental System*

IERs represent a step forward from traditional thinking that tends to focus on specific systems, channels, message formats, and the like when addressing interoperability. An IER is an information construct that is independent of the physical means by which the information exchange is accomplished. IERs provide the interaction piece of an operational architecture, and they establish a basis for both system-of-systems and individual system engineering to find the most cost-effective way of servicing warfighter information needs. However, they still force the architect to deal with a huge number of pairwise connectivity problems, and for a major weapon system the IER matrix becomes unwieldy, involving as many as several thousand individual information exchanges among dozens of platforms. As discussed in Section 3.3.8 and in Chapter 8, we believe that the JBI is a superior concept that will gradually replace IERs as the fundamental definition of how a system or user interacts with the information infrastructure.

Today, the most visible and controversial element of the DoD standardization approach to C^2 is the DII COE, which is a specific instantiation of the Joint Technical Architecture and takes the form of a defined software load that creates a standard execution platform. The DII COE, and the issues associated with it, have been addressed by a special study team, and the results are described in Chapter 8.

In addition to these initiatives and those described in Section 3.3.4.2, OASD/C^3I has defined an Outcome-Based Interoperability Process that seeks to link many aspects of requirements definition, system acquisition, exercises and experiments, and system engineering tools to infuse interoperability into system programs. An early prototype of a Joint C^4ISR Architecture Planning/Analysis System is being tested. C^4ISPs are now mandatory for all major system acquisition programs before beginning engineering and manufacturing development; these documents require the development of an IER matrix and the designation of the critical or top-level IERs that define the Interoperability KPP. C^4ISPs have proved a useful vehicle for flushing out interoperability problems and helping system designers think about the informational context in which their products must operate. We are encouraged by the level of attention that interoperability is receiving, but there are as yet few results to show for it in the real world of military operations. DoD has far to go to approach the success of the commercial world.

3.3.5.4 Migration to Improved Processes

These considerations suggest a number of measures to reform existing processes. We discuss them in the areas of operational architecture and requirements, technical architecture and standards, and acquisition.

Improving Operational Architecture and Requirements Definition. This is arguably the most important, and certainly the most intractable, area to reform. In study after study, the SAB has called for improvement to a process that takes far too long, overly constrains acquisition PMs, reinforces traditional stovepipes, and lacks any ability to balance and harmonize the various elements of the force.[11] The problem persists. The requirements bureaucracy is entrenched, the budget stakes are high, and the imperative to change for the sake of achieving the goal of Information Dominance is not yet widely understood or accepted in the operational community. Nevertheless, we feel compelled to state the case one more time.

Since acquisitions are conducted and money is appropriated system by system, there will always be a certain system-centric character to acquisition. However, the requirements that drive individual programs can and must be cast in the context of the complete force, including joint and coalition participation. We need a requirements process that reflects the way we plan to fight—joint, netted, interoperable, and, eventually, information-enabled. The C^4ISR Architecture Framework establishes a reasonable process and set of architecture products. Well thought-out operational architectures, validated through analysis, experiments, and exercises, must have precedence over system requirements and the resulting system architectures. In general, a System Program Director should conduct the program under requirements that suboptimize the single system because it will be an element of an optimized, integrated, interoperable force. For the information-centric CONOPS to work, and for future forces to be affordable and supportable, all elements must conform to an architecture that balances and allocates functions across platforms and systems.

This raises the troublesome issue of who should serve as the overall architect and how much power over individual system requirements and Service priorities that individual should wield. As mentioned earlier, the Joint Staff/J-38 is drafting an initial JOA and supporting set of JMAs.

---

[11] The November 1998 study *A Space Roadmap for the 21st Century Aerospace Force*, SAB TR 98-01 called for, among other things, creation of a force structure architect able to, for example, trade off performance requirements among space-based and air-breathing platforms.

An initial high-level operational architecture for a Joint Task Force has been defined, using the C^4ISR Architecture Framework; this provides a good starting point that must now be fleshed out in greater detail. Certainly there must be joint control, and the Joint Requirements Oversight Council would seem to be the logical holder of the baton. The Air Force still needs its own force architect, both to represent Air Force interests in the joint arena and to enforce the required requirements trades across Air Force space, air, and surface systems. Both joint and Air Force operational architectures should be closely tied to the *JV2020* vision, to the maturing concepts of operations of Air Expeditionary Forces, to exercises such as JEFX, and to system-of-systems engineering environments such as the emerging JDEP and the Distributed C^4ISR Simulation Network called for in Chapter 8.

Improving Technical Architecture and Standards Definition. From our consideration of how the commercial world succeeds, the following emerge as the overall characteristics of the process we seek for moving the current C^2 environment toward a commercial model:

- Identify communities of interest involving users, developers and supporters of C^2 systems and make them the primary drivers in the selection or, when necessitated by unique military circumstances, the development of standards. Ensure that architecture and standards are oriented to the needs of the system development and operational communities. Ensure, through a process of spiral development, experiments, and exercises, that they are fully mature before being released for operational use.
- Tie the definition and refreshment of this standards profile to the spiral process so that standards evolve with the systems that use them. Focus the standards activity on the adoption of the minimum set of standards adequate to achieved the required interoperability.
- Provide incentives for the use of standards through economic benefits to contractors and economic and operational benefits to users rather than through mandates. Exploit the fact that a good standards package reduces technical risk and development cost, allowing resources to be used to implement functionality, instead of repeating past experiences where standards mandates have consumed huge program resources in the effort to make them work.
- Make common infrastructure available such that it can be used when it meets system needs and as a contributor to interoperability. This will be especially true for common information services, including data maintenance, replication, access, and the communications environment.
- Develop, maintain, and evolve common technical models at all levels of the interoperability hierarchy and use these as the primary basis for interoperability.
- Provide top-level direction, vision, leadership, and enforcement to ensure consistent application of the interoperability strategy across organizations and programs.

As discussed more fully in Section 3.3.7, commercial systems rely heavily on layered architectures to maintain compatibility among heterogeneous computing environments, accommodate growth, and cope with technology evolution. Different elements in such a layered architecture tend to have different growth paths, and DoD needs to find ways to allow such non-synchronized evolution at various levels of its information infrastructure. For example, it's likely that the higher levels of the hierarchy in Figure 3-3, involving brain-to-brain interoperability between one human-computer interface and another, will change more rapidly than the lower levels, where legacy systems that cannot be instantly replaced will continue to provide the physical and messaging layers.

Open architectures that allow individual layers to be integrated or modified with minimal cost will be essential for DoD to take advantage of available commercial technologies in a timely

manner. Open architectures have other advantages, as well. The less vertically integrated a system is, the less specialized it is. Although many physical layer implementations are very unique to DoD systems, horizontal integration increases the opportunity for integration of commercial products, access to multiple vendors for the same product, and multiple uses for systems as a result of flexibility in configuration.

The basic message is that the commercial world views the business of acquiring, connecting, and using information systems in a fundamentally different way from that embodied in DoD's processes. Every path to the information-enabled force involves mastering and applying these lessons.

Improving Acquisition. Given that the future battlespace will be defined by an open, scaleable architecture, an evolutionary, streamlined acquisition strategy will be needed to enable rapid fielding of multiple future system increments. The operational architecture will be crucial as the foundation for establishing the constructs for information flow and must be tied to an acquisition strategy predicated on meeting EAF requirements. This EAF-based acquisition strategy is a significant detour from the current system-based acquisition strategy; however, without this change, we will continue to suffer from deficiencies in interoperability and delays in achieving the information systems needed to support the EAF. As an example, acquisition of Link-16 terminals through the JTIDS, MIDS, and JTRS programs is primarily based on each system's individual capability to fund Link-16 on that platform. The timing of these programs is not based on the needs of an EAF. As a result, until every system gets around to implementing Link-16 capability (10+ years from now), we will have multiple gaps in our key tactical data network.

Hence the basic reform in acquisition processes involves making interoperability and conformity to higher-level operational architecture a fundamental element of acquisition strategy. Many individual steps are needed, from better training of PMs and engineers in the problems of interoperability and their solutions to more realistic budgeting and planning for the effort needed to achieve and demonstrate interoperability. Once more, the real challenge is to break the mindset that a given program is concerned only with its own system and charged with making that system as good as it can be in isolation from the rest of the world.

New tools are available to help. The rapid move to simulation-based acquisition, driven by the increasing capability of modeling and simulation environments, makes it far more feasible to exercise a developmental system in a larger context to support engineering trades and validate or refine designs. The JDEP is a good example. Similarly, executable specifications that capture system design in the form of simulation objects can be used as a tool for ensuring that end-to-end performance in a system is defined well enough to quantify and achieve a specific and expected level of military utility. Executable specifications also help with interoperability by ensuring that a specific functionality can be reproduced in a different implementation or by a different vendor. Tools that define structured approaches for achieving interoperability such as Through Life Interoperability Planning (TULIP, see footnote 5) can be and have been used to evaluate interoperability and to predict and correct problems. To be most effective, these tools must be applied throughout the entire life cycle so that problems can be identified early, while they are relatively inexpensive to fix, and so that interoperability can be maintained through the application of effective configuration management. TULIP works by adding rigor to existing requirements definition, testing, and configuration concepts while emphasizing complete ("brain to brain") interoperability in a common sense approach.

All of this will increasingly be applied in spiral development programs. Requirements and designs will co-evolve, and functionality will often be delivered to the end users in increments. Complex information systems such as TBMCS are likely to continue to evolve over their operational lifetimes. The spiral methodology creates opportunities to correct early mistakes and to adapt to changing circumstances. Interoperability problems can be tackled in manageable chunks corresponding to each performance increment. However, it remains true that requirements must fully account for interoperability and must be predicated on the role the system will play in the larger force context.

To conclude this part of the discussion, we want to point out that from both interoperability and programmatic standpoints, the Air Force must take on the challenge of both "requiring and acquiring how we fight." The first "spiral" of this change is to migrate from a system-centric to a network-centric capability wherein we have the full compliment of necessary systems sufficiently networked to support EAF operations. This will require actions such as providing for centralized program elements (PEs) that support information systems (for example, a Link-16 PE) and then adjusting fielding plans and funding to support a fully capable EAF. This is a critical step in that it is the first major transition away from the historical system-based planning structure. Once that step is taken, the ground will be prepared for migration to the full JBI.

3.3.6 Integration of Operational and Technical Interoperability

In the preceding section, we stressed that technical and operational strategies for interoperability must be supported by effective implementing processes. Now we turn to the steps necessary to ensure that the technical and operational dimensions are properly harmonized and mutually supportive. As we have stressed throughout this chapter, interoperability is about providing warfighters with the technical means to realize the operational concepts of Information Dominance. To achieve true interoperability we must have a shared understanding of the situation among all the participants involved in a particular activity. This understanding must envelop the strategic, operational, and tactical perspectives, depending on the participant's function in the operation. Thus interoperability transcends the technical perspective and requires that operational doctrine and concepts, procedures, acquisition programs, and policies are tightly integrated within the Air Force, across the Services, and with our allies.

3.3.6.1 First Steps

Recent operational experience has shown that the fluidity of the operational situation demands enhanced ability to dynamically respond to rapid, significant changes. Technological advances are exponentially increasing our ability to collect and share data. However, that is insufficient. Since much of that data is acquired in ways that are not directly intertwined with our operational and tactical environment—always joint, often combined—we are not able to effectively synthesize the data into information. Thus we cannot develop the shared understanding necessary to take full advantage of our current capabilities. We may one day find that an opponent who has properly merged the technical and operational aspects of interoperability has the advantage in combat.

Since we want to tie our effort to bettering our operational capabilities, and because our national security strategy, related policies, and doctrine are relatively static, we can begin there. The Air Force has made great strides over the last few years with its doctrine development, but much

important work remains—for example, a publication that synthesizes current doctrine and tells the JFACC how aerospace power should be employed at the operational level.

The translation of that doctrine into CONOPS to support the C^2 of theater operations is in its infancy. We have earlier addressed the need to reform our processes for requirements formulation and system acquisition. The new requirements paradigm must closely couple technology with concepts for employing that technology to enhance operational capability. That coupling must be evident throughout the development and deployment cycle. Therein lies the motivation for a spiral process.

One possible construct for this integration is suggested in Figure 3-6. In the current paradigm of requirements and acquisition, operational deficiencies are derived by analysis of missions and forces, translated into system requirements, and implemented as a program. A typical "big bang" acquisition seeks to satisfy the full requirement at the conclusion of the development process. The right side of the figure shows how the spiral development process can be mated to the top-level derivation of CONOPS from national military strategy. Then operational concepts are used to formulate the operational view of a new system, and the iterations of the spiral allow the CONOPS, concept, and design to be incrementally refined and implemented. In this way, the operational dimension and the evolving technical solution can be kept consistent and evolved in parallel to an acceptable functionality for delivery to the user.

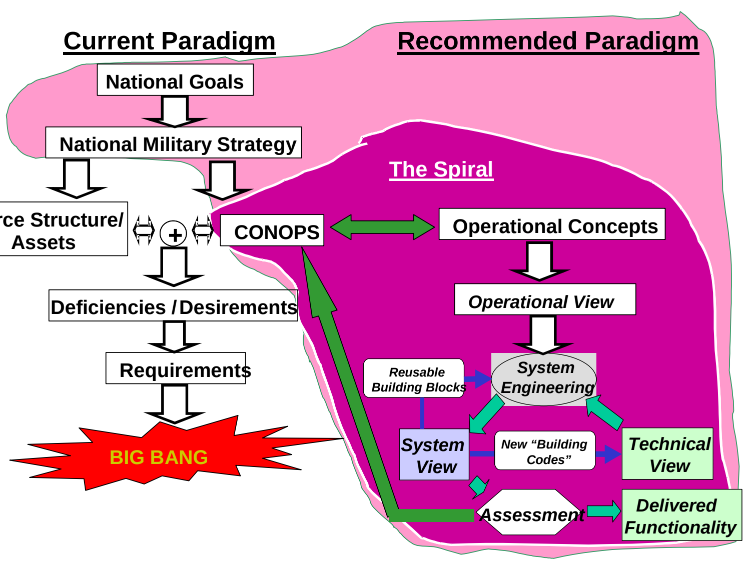


Figure 3-6. *The Traditional Linear "Big Bang" Approach to Delivering Military Capability Should Evolve Into One Linking the Development Spiral to Refinement of CONOPS and Concepts*

The work of the AC2ISRC in this area is essential in the spiral paradigm. For that work to be most useful, however, it needs to be expanded to address joint and coalition operations. The AC2ISRC should team up with representatives from the Army and Navy in the very near term. Organizations such as the Army's Training and Doctrine Command and Communications and Electronics Command, the Navy's Naval Warfare Development Command, and the Marine Corps Warfighting Laboratory seem to be key organizations to effect this refinement. This effort

is critical to shaping the development, deployment and operation of Air Force C^2 systems and to effectively training the warriors who will use them.

These operational concepts should be chosen to effectively cover the likely set of future operational environments, as opposed to an exhaustive set. The chosen set of operational concepts should then drive the development of an appropriate operational architecture that will in turn support the development of the necessary system views to support force structure and system developments. These will then provide a basis for policy makers, developers, and operators to share a common understanding of

- How system capabilities will support the planning and execution of operations
- New operational opportunities afforded by new technology and related systems
- How to operationally test and certify the sufficiency of the systems
- How to interact to further enhance system functionality through development spirals

3.3.6.2 The Context

Since these products will be tremendously complex (and will evolve as a function of the insertion of refinements—enabled by technology enhancements to operational concepts), to be truly useful they will need to be captured using knowledge management technology. This will be helpful in two ways, because in addition to helping the developers, the knowledge developed during the development of the products will also be important to the people who actually use the systems that result in planning at the strategic, operational, and tactical levels, and in executing operations.

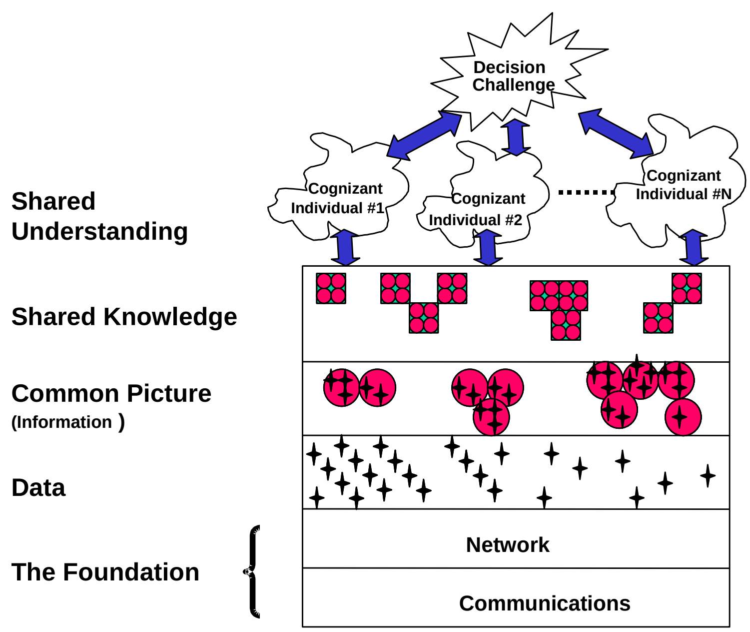


Figure 3-7. *Technology Will Increasingly Allow Automated Processes that Aggregate Data into Information, Interpret Information to Create Knowledge, and Disseminate Knowledge to Allow Shared Understanding*

We must now turn to another dimension of the interoperability challenge—the technical perspective. Here we begin to describe the relationship between the decision space shared by operational commanders and other decision makers, the information and data that they require, and the communications and networks foundation on which the process stands. Figure 3-7 depicts the end-to-end interoperability construct for decision support. This is, of course, merely an expansion (although an important one) of the layered interoperability construct in Figure 3-3.

In the long term (5 to 15 years) we can anticipate the emergence of technology that will allow us to incrementally automate the knowledge formation layer. Even though it is possible to assist commanders and other operational decision makers with computerized decision support systems based on Bayesian logic and probabilistic estimates, shared understanding will be the limit of achievable information support for the foreseeable future. However, even this technology has the potential for tremendous (perhaps order-of-magnitude) reductions in decision cycle times. This will be true even though we can anticipate that the available information will grow exponentially. The Defense Advanced Research Projects Agency, the Service laboratories, and industry are investing in these areas. We must continue those investments, and AFRL/HE and AFRL/IF should take the lead in sponsoring and encouraging work on information models (see Chapter 8) to focus the inference engines and other techniques being pursued.

In the mid-term (3 to 7 years), automation of data integration into information will be enabled by technology that is emerging today in laboratories, system centers, and industry. This technology will significantly reduce the current 72-hour ATO battle cycle so that we can more effectively support dynamic targeting as well as the Army's and Navy's 24-hour battle cycle targeting requirements. It will also allow us to more closely couple and enhance the effectiveness of information exchanges with our coalition partners. AFRL/IF and ESC should team and add emphasis on the Adaptive Sensor Fusion program and migrate the best of breed into the C^2 environment annually. This effort should be focused consistent with the information model described in Chapter 8. The progression just described is sketched in Figure 3-8.

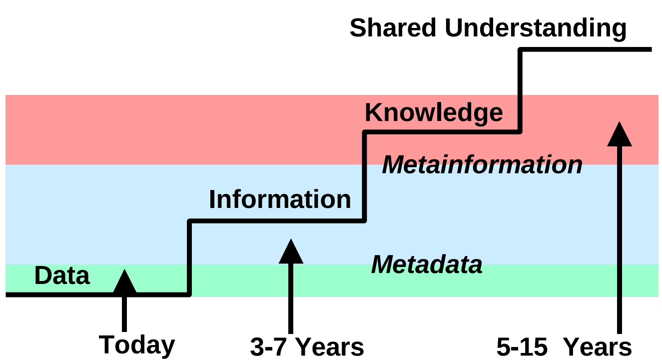


Figure 3-8. *The Progression, as Technology Advances, from Data to Understanding*

Once more we note the vital importance of shifting our focus from platform-centric to network-centric, and eventually to information-centric operations. As communication networks have become more widely deployed, the opportunity for enhanced cooperation and coordination among the C^2 elements is becoming real. Over the past few years, the concept of network-centric operations has become common. Applications are increasingly able to communicate and

coordinate by exchange of information through common networks. Now the evolution of communication and computing technologies has resulted in a new opportunity, that of information-centric operations. Concepts such as the JBI are rooted in the idea of having a "common distributed and virtual information environment" accessible by all of the systems and people engaged in operations.

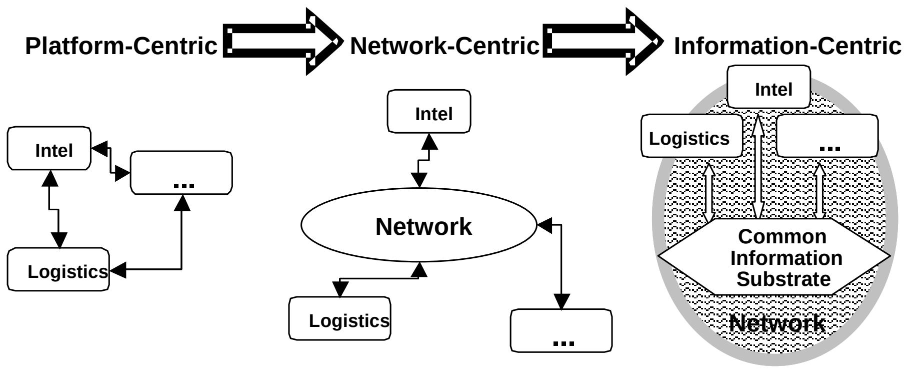


Figure 3-9. *The Evolution from Platform-Centric to Information-Centric Operations*

Figure 3-9 depicts the evolution of the integration of C^2 system functional areas into a C^2 enterprise. When systems were developed as independent platforms, communications between them was, at best, done with dedicated links. As networks developed, the independently developed C^2 applications and modules were able to exchange information through a common network. However, in both the platform-centric and the newer network-centric approaches, the systems and their associated software applications generally "owned" their associated data. Information was exchanged between applications, rather than viewing the information as the common integrating aspect.

The information-centric approach attempts to fundamentally shift the paradigm. Recognizing that interoperability and integration of C^2 functional areas into a C^2 enterprise requires the ability to share and mutually understand knowledge, information, and data, the information-centric approach starts with the premise of *information primacy*. The prime focus is the information architecture and model to enable different command elements to operate in a coordinated manner. This is enabled through the common information substrate. Applications, while designed to provide the commander and staff with the ability to use the information as needed, are explicitly designed to operate on the common information objects—storing, processing, manipulating, and accessing them as needed.

Interaction between C^2 functional elements is then implicit. Since they are operating on the same information objects, when an information object is created or modified by one element, other elements have immediate access to the object. The information substrate provides the mechanisms (such as publish/subscribe) to notify the C^2 elements and associated applications when new or modified information objects of interest are available.

3.3.6.3 Bringing It Together

Finally, we are in a position to discuss how it should come together. The technical perspective arises from the application of technology to produce shared understanding and the basis for

collaboration and cooperation among warfighters. The JBI will be the key enabler of the essential information-centric thrust toward force-wide interoperability. Figure 3-10 suggests the way progressively higher levels of cognitive support to commanders and their forces can be thought of as knowledge, information, and networking environments. The operational perspective, then, arises from the improved CONOPS that are enabled by this information infrastructure and evidenced in reduced decision timelines, superior access to timely and relevant information at all echelons, and the ultimate outcome of operational success in the form of mission accomplishment, survival of friendly forces, minimum collateral damage, and maximum efficiency in applying force to achieve military objectives.

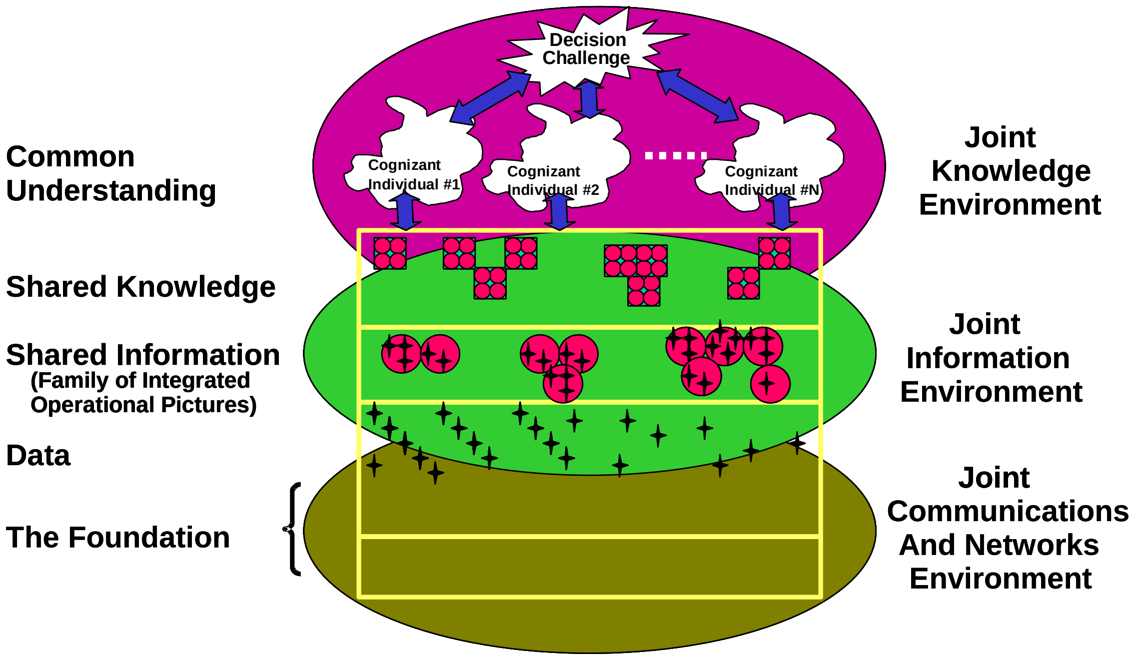


Figure 3-10. *Technical and Operational Dimensions of Information-Centric Operations Come Together in Networking, Information, and Knowledge Environments that Support Warfighters at All Echelons*

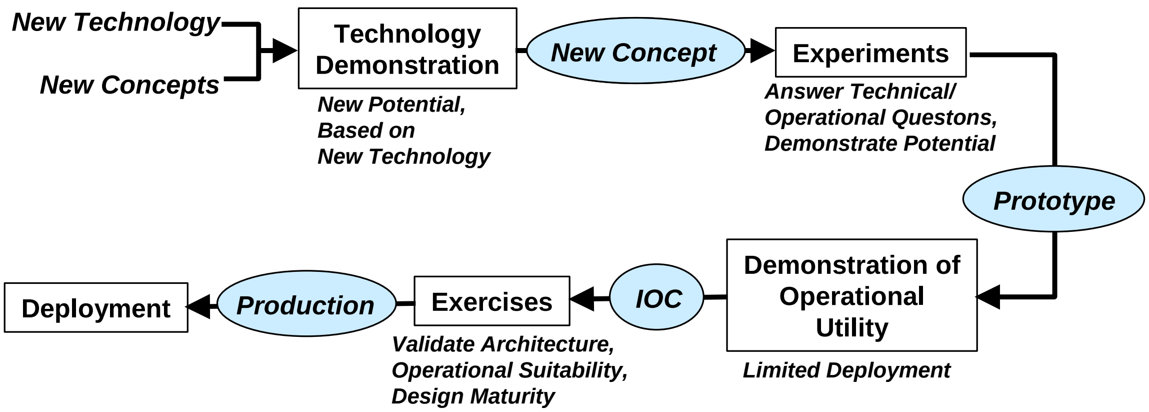


Figure 3-11. *Demonstrations, Experiments and Exercises Are Key Elements of Integrating Operational and Technical Solutions to Produce New Capability*

The fusion of emerging technologies and the new CONOPS they make possible will often involve three related but distinct kinds of activities that progressively establish the feasibility and utility of a new concept and of the corresponding new system or systems. These are technology demonstrations, experiments, and exercises, and they are not uncommonly mixed up. It's important to keep them straight, because each plays a particular role. For present purposes, we define them as follows:

- **Technology Demonstration:** a limited deployment of a new or improved technology, system, architecture, or procedure to provide information and insight concerning the maturity and utility of candidate approaches to enhance military capability
- **Experiment:** a limited deployment of new systems, architectures, or procedures in a meaningful operational context to evaluate their utility, compare alternative concepts, refine requirements, and support operational and acquisition planning
- **Exercise:** a limited deployment of new and existing systems, architectures, and procedures with the involvement of operational personnel to validate their readiness for use and support training and other preparations for early introduction of new capabilities into the force

An exercise tries to emulate the real world operational environment and place realistic stresses on the concepts or equipment being exercised. It is intended to get as close as possible to real operations. In some sense, exercises provide the military with a substitute for a commercial market as a testing ground for alternative futures. An experiment, by contrast, is aimed at answering a set of questions about new concepts and systems. If hoped-for results are not achieved, the experiment is not a failure but rather a source of valuable information about previously untested ideas. Finally, a technology demonstration provides a channel for technology users to interact with possible customers and show the kinds of capabilities that emerging technology may make possible. Figure 3-11 is a somewhat idealized flow from proposed technology and concepts to fielded systems that indicate the place of each of these events.

Improved interoperability, and, in the larger sense, improved military capability in general, result from the marriage of new operational concepts and the technical means to realize them. The vision of robust, flexible, end-to-end interoperability, leading to true "brain to brain" cooperation and shared understanding, will become reality in the JBI and is the essence of information-enabled warfare.

3.3.7 Layered Architectures

In this section, we continue and expand the discussion of applying the strategies that have proved so successful in the private sphere to attack interoperability problems in military C^2 systems. Architecture is the foundation and enabler of C^2 and is thus a thread running throughout this Study. One of the central principles that underlie the success of the Internet and, in general, the approach of commercial systems to interoperability, is the use of layering in the architectures of networks and nodes. Layered structures provide successive abstractions from implementation details and establish broadly useful interfaces to enable processes to interact.

In the course of the study, we have identified and investigated a number of other technical issues that are closely related to the JBI. These include information modeling and other aspects of establishing a shared information environment. Chapter 8 of this Volume contains a focused discussion of these matters and a recommended path to realize the information technology foundation of the JBI. Here, we address the general topic of layered architectures and their role in implementing highly interoperable information systems.

3.3.7.1 Commercial Layered Architectures

The layered architecture of the Internet makes the ready interoperability of the World Wide Web possible. It also provides a wide range of benefits to the commercial world. For example, it makes possible the creation of Web-based businesses. A properly layered architecture would provide numerous benefits to the Air Force, some of which are described below. The Air Force, and DoD in general, should adopt a layered approach to communications architecture. It is important to understand how the civilian system is structured, and how the benefits flow from that, in order to understand how the Air Force, and DoD as a whole, should structure their architecture and what benefits can be expected.

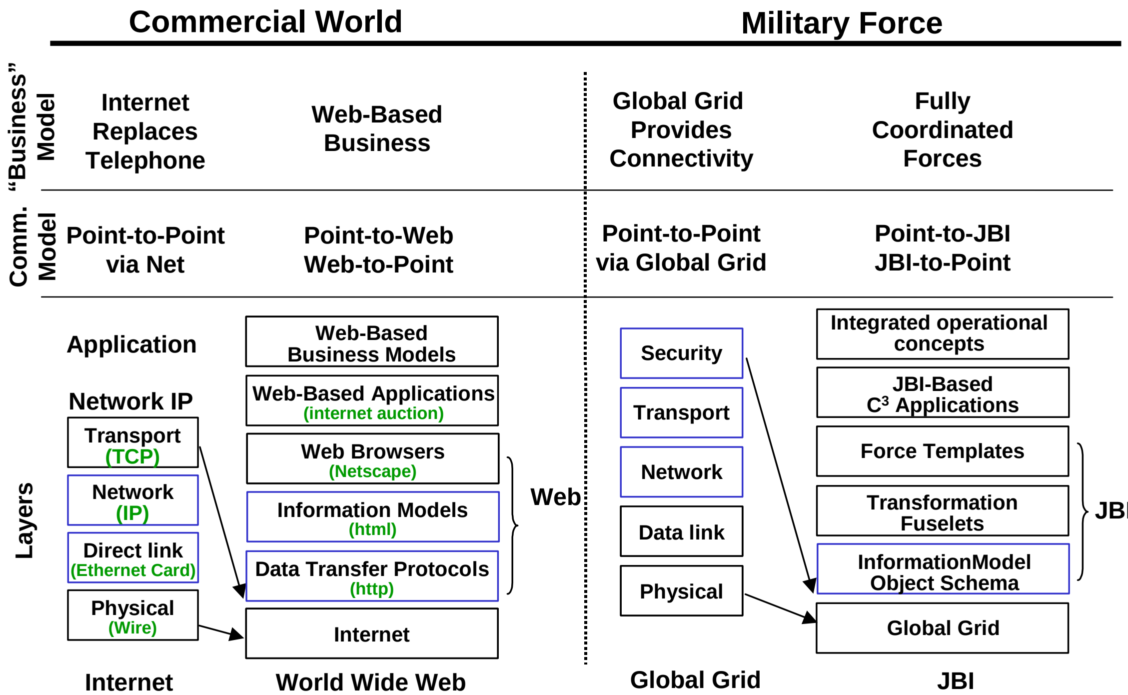


Figure 3-12. *Commercial Layered Architectures Point the Way to Interoperability in* C^2

The layering on the commercial side is represented by the left-hand side of Figure 3-12. The first column represents the layering of the Internet. The bottom layer contains the physical connections over which the data flows. It includes phone lines, microwave links, and fiber. The second is the equipment and protocols to send bits over the physical layer. The top two layers describe how data are incorporated in packets and switched from computer to computer reliably. These layers describe the Internet, and for the first two decades of its existence, the Internet functioned primarily using these layers. In those days, Internet users connected to a remotely located computer, logged on, and used the resident software. The transformation between data and information was done on the hosting computer. Thus, what was supported was point-to-point communications. In effect, the Internet replaced the phone company network. There was also limited, low-level file transfer, but conventions on the format and meaning of data were settled on a point-to-point basis. There was no thought of an "Internet-based business." Because the architecture was properly layered, the Internet survived several generations of changes in the physical layers and the computers implementing the data links, and the evolution of TCP from earlier transport protocols. Each layer could evolve at its own pace without upsetting the other layers. Furthermore, multiple generations of each layer could coexist and interoperate. This was held together by the relative stability of the IP layer, and to a lesser extent the TCP layer. That is, provided a user has a computer interface board that can send and receive TCP/IP packets, the user can connect to the Internet with the expectation of being able to exchange data with other computers, including those yet to be designed and built.

The next column shows the World Wide Web; this is layered on top of the Internet. The addition of data transfer protocols and information models allows the Internet to support the exchange of information rather than data. This means that a user thinks of a Web page putting information "on the web" and of using a browser to pull information "off the Web." Even though all the

communication actually occurs point to point in the Internet layers, it is sensible to think of each system communicating with the Web, rather than with other computers on the Web. There are numerous benefits to this approach. One of the most important is that a developer can design and test an application that can interact with all the needed computers by making sure that it interfaces to the Web. Thus, a company like Amazon.com can develop and run a Web-based application allowing customers to find, browse, and purchase books without testing whether it works on each Web browser, operating system, or computer that a customer may have. Likewise, a vendor can develop a computer or Web browser without testing it against all the sites a customer may want to visit. This in turn allows the development of Web-based business models and Web-based businesses. The relative stability of the data transfer protocol and information models is the key to allowing this to work; anyone can design Web-based applications to *html* and related protocols such as Graphic Interchange Format with confidence that they will work with all types of computers and systems.

3.3.7.2 Layered Architecture and the JBI

The right-hand side of Figure 3-12 shows what a layered architecture for the military would look like. The third column of the chart shows a connectivity structure. The requirements for this structure differ from those for the Internet in that it must be secure against physical and electronic attack, must support real-time communications, and must interact at high bandwidth with highly mobile platforms such as combat aircraft in flight. The network layer of this will probably be based primarily but not entirely on IP, and the physical layer will include wires, fiber, radio waves, satellite communication (SATCOM) channels and so on. Large sections of the physical layer will be based on legacy systems (for example, SATCOM). A crucial challenge will be to organize these legacy systems to provide a connectivity layer with the requisite robustness, capacity, and flexibility.

The JBI will be built on top of this Global Grid in the same way that the Web is built on the Internet. If the architecture for the JBI is correctly designed, it will provide two large benefits. One is that it will allow PMs to ensure that their platforms and systems will be interoperable with all other systems by specifying and testing their interaction with the JBI, rather than individually with each platform with which they must interact. The other is that it will enable the development of JBI-based C^4ISR applications. The availability of these applications will permit the development of operational concepts for fully cooperative forces.

The layers can evolve independently at their natural pace. This allows the components of the C^2 system to keep pace with commercial developments in a manner consistent with acquisition law and policy while remaining interoperable with each other and the force elements. The major interoperability payoffs will come in the way layered architecture facilitates the development and evolution of the JBI. This is explored more fully in the next section.

3.3.7.3 Interoperability and Security

A fully interoperable force is vulnerable to information warfare attacks on its C^4ISR systems. These can take many forms, including physical attacks on its links, jamming of links, attempts to insert false information into RF links, the use of captured equipment to insert false information, and attacks by agents within the system. The more interoperable the system, the greater the effect that bad data can cause. The periodic virus “epidemics” on the Internet are an example.

In general, the Air Force does a good job of protecting its links from attack and jamming, and the use of encryption impedes both eavesdropping and the insertion of false information over links. However, there are two areas that merit attention. One is to ensure that the Air Force C^2 system degrades gracefully when the connectivity bandwidth is reduced by physical attack or jamming. The Army Enterprise Architecture provides a good example of this. The other area is to make sure that the layered architecture contains adequate security provisions to limit the spread of bad information inserted using equipment captured by inside agents and to remove it as efficiently as possible.

3.3.8 Interoperability and the JBI

Over the past 3 years, the SAB has developed and refined the JBI as the recommended goal toward which all C^4ISR systems should migrate.[12] The power of the JBI concept is especially notable in the area of interoperability. This can be seen most clearly by comparing the current situation, where interoperability is defined and worked through the IER matrix, with what will be the case once the JBI is implemented.

The idea of the IER represents a major advance over earlier ways of looking at interoperability. It substitutes an information construct for the older view based on specific channels, links, terminals, and message sets. An IER can be mechanized through any link or channel that satisfies its timing, data exchange, and security requirements. It is thus a great step toward openness and an information interface approach. However, the sheer number of IERs and of platforms and systems among which they must be defined makes this still a very awkward and inefficient way to specify, implement, test, and certify interoperability. Any given C^4ISR or weapon system is likely to interact with dozens of other systems and to require thousands of IERs, as recently prepared C^4ISPs illustrate. Each pairwise relationship among platforms creates an interface that must, in principle, be verified. The C^4ISP prepared for the Joint Strike Fighter (JSF) documents several thousand IERs, some of which specify 50 or more other platforms and systems with which the JSF must exchange information. Those IERs that are critical—about 70 in the case of JSF—involving dozens of platforms, must be tested by JITC before the JSF can be approved for production. This effort can only ensure that the JSF is interoperable with those platforms known to the writers of the C^4ISP. Since the JSF, if successful, will be operated by the Air Force and other Services for many years after the C^4ISP is written, the initial set of platforms is likely to be only a fraction of those with which the JSF must interact over its service life. Thus, despite the large effort to compile the IERs and then to develop and test them, interoperability of the JSF will periodically be a problem for the Air Force as new platforms come on line.

[12] SAB report, *Information Management to Support the Warrior*, SAB-TR-98-02, December 1998; SAB report, *Building the Joint Battlespace InfoSphere*, SAB-TR-99-02, December 1999.

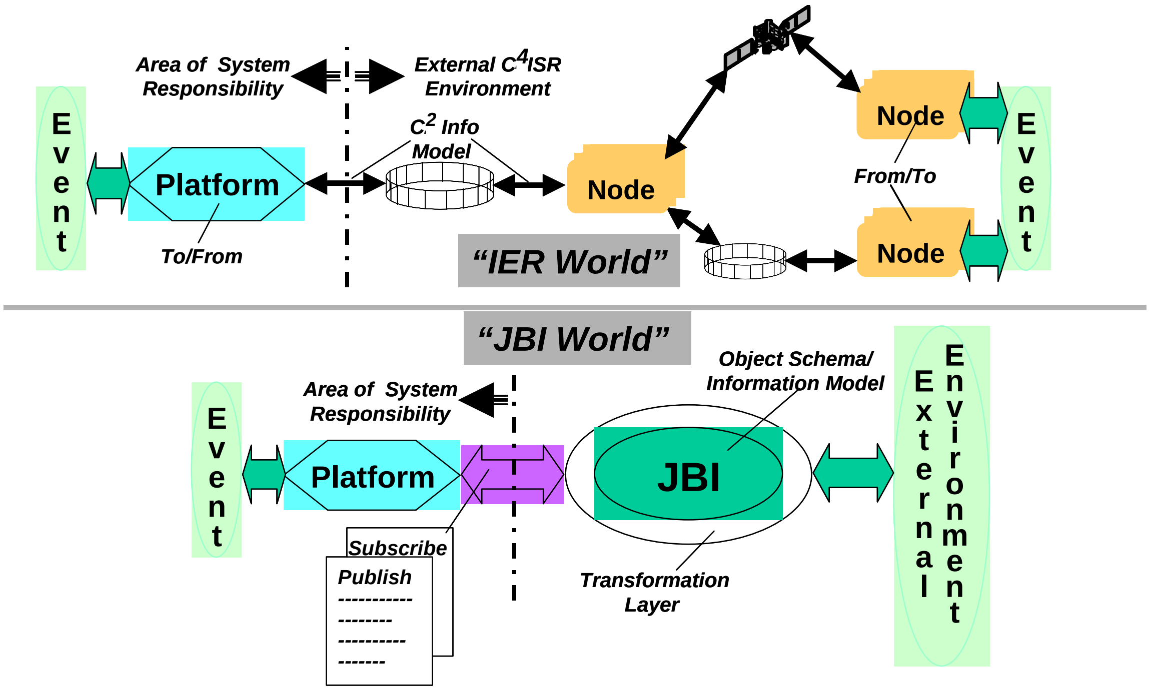


Figure 3-13. *The JBI Greatly Simplifies the Specification and Assessment of Interoperability*

This contrasts sharply with the situation in a world with a layered JBI architecture. The interoperability requirements are now to provide a set of data links and other channels to ensure connectivity to the JBI, and to ensure correct transmission, reception, and processing of information according to the JBI information model. While this last requirement will be more complex than any single current IER, it will be far less complex to deal with than a collection of thousands of them. Interoperability testing is simplified because it can now be done with a single JBI instantiation rather than with a multiplicity of platforms. Furthermore, future interoperability with new systems is assured, provided they similarly conform to the JBI interface. Figure 3-13 highlights the difference.

With the JBI, the same *physical* events may occur in executing an information exchange as with today's platform-to-platform view, but the *logical* process is completely different. In the JBI, the plethora of IER interfaces reduces to a single, albeit very complex, interface between a platform and the InfoSphere. Interactions with the external environment via the JBI are accomplished through publish-and-subscribe mechanisms that are far simpler to deal with than hundreds or thousands of specific information exchanges. The responsibility for the rest of the process, from connectivity among platforms to consistent treatment of information, is transferred to the JBI. The transformation layer (implemented with "fuselets") around the central object repository facilitates the definition and implementation of this interface to a legacy or future system. Now the KPP becomes implementation of the single JBI interface. This, in combination with enhanced access to diverse information services, makes the JBI the fundamental solution to the technical aspects of interoperability.

3.4 Recommendations

The emphasis of this study has been on near-term actions to significantly improve Air Force C^2 in the next 5 years. In the area of interoperability, most of the recommended actions will begin to pay off in this timeframe, but also will entail fundamental changes in processes, systems, facilities, and other things that will take longer to complete. We have spent many years getting ourselves into an interoperability quagmire, and it will take a while to get ourselves out. A number of interoperability-related recommendations are contained in Volume 1 of this Study report. The panel recommends the following additional actions, grouped by major areas of interoperability problems.

3.4.1 Near-Term Interoperability Corrective Actions

3.4.1.1 Specific Interoperability Problem Fixes

Task AC2ISRC, working with related organizations such as the Commanders in Chief Interoperability Program Offices and the Joint C^4ISR Battle Center, to identify specific interoperability problems such as those cited in Section 8.3.2. The list should be prioritized such that problems correctable by simple technical changes, corrections to TTPs, or other inexpensive measures are flagged and given emphasis for quick attention. Task AC2ISRC to collect and analyze interoperability problem reports and task all field organizations to report such problems to the Center.

3.4.1.2 Coalition Interoperability Focal Point

Establish an Air Force focal point to coordinate policy, strategy, and actions involving C^4ISR interoperability with allies. Specific actions include:

- Define a process for addressing coalition interoperability problems, including linkage to the Air Force POM and budget development process, to ensure that proper priority is placed on them.
- Explicitly address allied roles in warfighting plans, including capabilities that complement U.S. forces and guidance for allied C^4ISR investments. Establish warfighting contexts that clarify national roles and policies and whether interactions will be based on alliances, *ad hoc* coalitions, or bilateral agreements.
- Coordinate allied participation in exercises and experiments, including definition of exercise and wargame content that provides a sound basis for exploring coalition interoperability issues and operational roles.
- Maintaining continuity in U.S. positions and representation in solution of protracted issues.
- Coordinate foreign military sales activities that bear on coalition interoperability.

3.4.2 A Framework for Interoperability

3.4.2.1 Centralized Coordination of Interoperability Requirements and Activities.

As part of the overall centralized coordination and control of C^2, establish a process and appoint an Office of Primary Responsibility to oversee the development of interoperability requirements and to direct appropriate actions to resolve interoperability shortfalls. Specific actions include

- Vigorously support the development of Operational Architectures (OAs) and apply the DoD C^4ISR Architecture Framework as an intrinsic element of requirements definition and validation.

- Move to an architecture-driven requirements model and process. Insist that emerging OAs provide implementable guidance for developing individual system interoperability requirements and that compliance with these be made a fundamental condition for programs to proceed.
- As the JBI matures, migrate the focus of C^4ISP development from "Networthiness Certification" to "JBI Certification."
- Challenge and oppose platform-centric thinking and decisions that inhibit interoperability. Require, as part of system requirements analysis and validation, that individual system requirements be justified in the context of the overall force of which the system will be an element.
- Establish a focal point for modeling, simulation, and analysis (MS&A) to ensure that tools and databases used to work interoperability are developed, maintained, and made available and to oversee validation and verification.
- Coordinate emerging C^2 architectures, especially for the JBI, with other Services and with allies.
- Coordinate architectures, system requirements, procedures, and other aspects of interoperability with other Government entities (Department of State, the Federal Emergency Management Agency, etc.) and with NGOs with which the Air Force works during natural disaster responses, humanitarian operations, etc.
- Coordinate the planning, objectives, participants, and products of exercises, experiments and demonstrations to obtain maximum data and insight for the continued refinement of architectures, system requirements, and interoperable TTPs.

3.4.2.2 DoD-Wide Information Services Process and Information Repository

Work with DISA and the other Services to establish an Information Services process as part of both near-term actions and migration to the JBI. Specific actions include

- Define and validate a taxonomy of joint and coalition warfighter information needs; exploit C^4ISPs, existing data models, and other sources; implement Service, joint and coalition doctrine; and establish a process to refine the taxonomy over time.
- Define the characteristics of the JBI information repository (object schema) as requirements for the information model and define a process to migrate current models to the JBI objective; characteristics include metadata standards and repositories, metadata definitions for model elements, segmentation and hierarchy, transformation and traversal engines, methods for incorporation of legacy and local data bases (wrappers, translators, etc.), and abstraction mechanisms.
- Direct Air Force Space Command to participate in JBI development and to examine the emerging JBI architecture for implications for network defense and other aspects of information operations.
- Establish a process to select, develop (where necessary) and refresh standards for metadata, publish/subscribe, and other attributes of the JBI information repository and services.
- Coordinate with individual programs (GCCS, GCCS-AF, TBMCS, the Deliberate Contingency Action Planning and Execution System, JMPS, etc.) to migrate their information models and data repositories to the JBI. Specifically, direct actions and provide funding to web-enable and Extensible Markup Language-enable legacy and developmental C^2 systems.
- Define and fund development of needed common infrastructure.

3.4.2.3 Architecture and Standards for Interoperability

Take specific steps to define and implement the architectural foundation of an Internet-like JBI, including

- Direct Air Force Materiel Command (AFMC), through ESC, to require layered architectures for C^4ISR systems, especially the JBI. Facilitate communities of interest, in the Air Force, with the other Services, with allied nations, and with the private sector, with support funding as appropriate, to define standards, architecture, and common infrastructure and to articulate their proper application and benefits. Use these communities of interest as the vehicle for selecting and evolving a minimum required set of standards to define each layer.
- Make the incremental development and refinement of the JBI information model a core element of the Air Force C^2 program as a whole and of the spiral JBI development in particular (See Chapter 8 for additional details).
- Direct AFMC, through ESC and AFRL/IF, to emphasize the Adaptive Sensor Fusion program and migrate the relevant results into the C^2 environment annually. This should be linked to the evolution of the JBI information model, which includes processes for data aggregation and fusion.

3.4.2.4 Facilities and Procedures to Evolve an Interoperable Force

Create a Distributed C^4ISR Simulation Network environment and accompanying procedures for hosting, evaluating, developing, and exercising interoperable C^4ISR systems. Specific steps include:

- Establish a network linking primary C^4ISR sites, such as the experimental C^2 facilities at Langley and Nellis AFBs, the CUBE at Hanscom AFB, the C^2TIG at Hurlburt AFB, the TACCSF at Kirtland AFB, and possibly others. Establish procedures and provide funding to use this network to refine TBMCS, support Distributed Mission Training, participate in exercises and wargames, and in other ways support the fastest possible transition to information-centric operations for the EAF.
- Participate in the JDEP, including appropriate linking of the Air Force C^4ISR network just described with similar networks of the Army and Navy.
- Direct ACC, the AC2ISRC, ESC, Air Force Operational Test and Evaluation Center, AFRL, the TBMCS program, and other key players in joint and coalition interoperability to vigorously pursue contacts with appropriate Army, Navy, and allied organizations and activities to promote interoperable architectures and systems and compatible TTP. Include the specific problems and issues documented in Section 8.3.4, such as the disconnect between the current ATO timeline and Army needs for short-notice target notifications to attack helicopters.
- As part of the workup to a deployment vulnerability window, require the participating units, including the AOC staff, to undergo interoperability training and pass an evaluation. The C^4ISR network or JDEP could be used in a distributed training mode to support this.

3.4.3 Interoperability in Acquisition and Testing

3.4.3.1 Interoperability Across the Acquisition Process

Ensure interoperability is embedded in all phases of system acquisition. Specific actions include

- Define and enforce appropriate interoperability content in the documentation for every acquisition milestone.
- Explicitly account for interoperability in program and contractual documents (Single Acquisition Management Plan, Statement of Objectives, Test and Evaluation Master Plan, etc.). Develop explicit interoperability content at all levels of the hierarchy defined in Figure 3-3 in the definition of outcomes of individual spirals.

- Work with JITC, Joint Staff J-6, and others as appropriate to develop and refine interoperability testing and evaluation methods, including live testing, system integration laboratory tests, and MS&A.
- Exploit proven tools and methodologies by facilitating their incorporation into system engineering environments and by requiring contractors to define and employ mature methodologies for dealing with interoperability; make this capability a source selection criterion.
- Where appropriate, require interoperability assessment of developmental systems using the environment described in Section 8.4.1.4, as a central element of simulation-based acquisition.

3.4.3.2 Interoperability Working Groups

Direct the establishment of appropriate Interoperability Working Groups for acquisition programs to provide the forum in which common issues beyond the control of individual programs can be surfaced, defined, and resolved.

3.4.3.3 Development of TBMCS and JBI

Take actions to achieve the fastest possible fielding of required C^2 capabilities, with TBMCS as the near-term focus and JBI as the overall strategy. Specific actions include

- Host TBMCS on the distributed environment described in Section 8.4.2.4 and evolve it to achieve the required C^2 functionality for the EAF.
- Accelerate the development of the JBI, including the key actions described in earlier recommendations and using the distributed environment and results of demonstrations, experiments and exercises.
- To focus JBI development, select an important immediate problem and make it the basis for initial JBI functionality. We suggest that this problem be the targeting of a time-critical target such as a pop-up surface-to-air missile system. The corresponding JBI prototype should include both national and theater sensors such as Rivet Joint, U-2, and Global Hawk, with reachback to national intelligence sources, a Battle Command Center, and strike aircraft. If this is begun promptly, a demonstration as part of JEFX 01 is possible.

3.5 Conclusion

There are many reasons that the “fog of war” can dominate the battlespace. The right information, delivered in a timely, consistent, and efficient manner, may often succeed in clearing the fog. Three situations need to be considered: First, given that the ISR needs are met, and unambiguously transmitted to the right action address, efficient and standardized interoperability may carry the day. Second, if the ISR needs are not met, interoperability may very well be a secondary issue, as the lack of information may result in no action. In this case, a defensive posture may still allow order to prevail, so that operating forces can live to fight another day. In the third case, the most destructive result could occur when the wrong information is passed, or sent to the wrong people. This could mean disaster to an otherwise dominant force. Lack of adequate interoperability may cause conflicts or fratricide in strike execution, late delivery of essential information, and asynchronous or faulty command action. To avert such a situation, unambiguous, efficient interoperability must occur. This is a complex problem, for which a solution is absolutely essential to the effective prosecution of warfare.

Appendix 3A
Interoperability Panel Charter

The Interoperability Panel (IOP) will examine both the underlying technical issues and the operational/procedural issues associated with achieving robust interoperability among the elements of an aerospace force. The objective of the Panel's inquiry is to understand the factors which enhance or impede interaction among force elements, to identify actions (including organizational and procedural changes) which promote robust interoperability, and to recommend technology and system developments which will improve the capability of the Air Force C^2 infrastructure to respond to the full spectrum of operations likely to be required of aerospace forces in the 21st century. Those missions range from humanitarian relief and low intensity conflict to major theater warfare and cover the full spectrum of operational elements. The panel will exploit relevant results from recent SAB studies, including those dealing with Aerospace Expeditionary Forces and Information Management to Support the Warrior, and will coordinate closely with other panels, especially those on Technology and Concepts and System Definition, on areas of mutual interest; focal points will be established with other panels as appropriate.

The prevailing ideas about jointness and interoperability within the DoD and the Services are, at best, inadequate, and, at worst, wrong and counterproductive. It is generally believed that "standards-based design" is sufficient to achieve interoperability. This is demonstrably nonsense. In general, the seductive appeal of simplistic standardization mandates seriously impedes strategies that can actually achieve interoperability. Effective means of coping with rapid technology evolution, especially in the commercial marketplace, so as to maintain compatibility among defense equipments based on different technology generations are almost entirely lacking. Bureaucracies with entrenched interests are limited in their insight into the real issues and reluctant to change. The problems with interoperability within U.S. defense and international agencies are compounded in the arena of coalition operations.

Among the specific issues the panel will address are the following:

- Define the information processes which underpin information superiority in the battlespace and the associated technical issues such as
  - A common information model for warfighter interactions
  - Efficient mechanization of data, information and knowledge repositories and approaches for sharing their content
  - Effective development and maintenance of information intensive systems

- Examine the IER construct as defined in recent Joint Staff publications, as well as associated policy and directives, as a basis for achieving robust, all-condition interoperability
- Define the levels of interoperability, including connectivity, communication, and compatible ("brain-to-brain") information and knowledge processes
- Identify and evaluate technical issues associated with terminals, information environments, networks, waveforms, standards, and procedures and changes that can improve interoperability. For example, how far will compatibility with the JTRS specification go in achieving interoperability among communications nodes?

- How should the current DoD C^4ISR Architecture Framework and supporting documents such as the Joint Technical Architecture be evolved to facilitate true, operationally meaningful interoperability?

In keeping with the overall study Terms of Reference, the IOP will address both near term (present to 2005) and farther term recommendations to the Air Force leadership. Among the areas where immediate action to promote a more connected and interoperable Air Force are

- Leverage recent and ongoing efforts in multiple programs to define IERs and document interoperability requirements in C^4ISPs
- Build interoperability content into exercises, experiments, wargames, etc., to refine and validate IERs, diagnose and correct interoperability problems, and improve overall requirements in areas such as communications capacity
- Implement the recommendation of the 1998 SAB Space Roadmap Study to establish a force structure architect with control over system requirements; interoperability would be a key aspect of this function
- Start the development of a Common Architecture Data Model as called for, but not implemented, in the DoD C^4I Architecture Framework; make open, information-based architecture a fundamental requirement of the requirements and development processes for all systems

In short, the Interoperability Panel faces a major challenge in articulating the true problems that interfere with interoperability and in formulating actionable recommendations which will, inevitably, involve unpalatable organizational, cultural and programmatic changes. However, the future of U.S. military success depends critically on information superiority, and recent experiences in Kosovo and elsewhere have shown decisively the shortfalls in existing processes and programs. The Interoperability Panel will seek to define policy, organizational, technology, system, and operational actions that can rapidly close existing interoperability gaps and lay a solid foundation for information-enabled warfare in the years and decades ahead.

Appendix 3B
Interoperability Panel Membership

Dr. John M. Borky, Chair
Chief Scientist
Tamarac Technologies, LLC

RADM John R. Batzler, USN (Ret)
Senior Warfighting Analyst
Center for Naval Analyses

Prof. Claude R. Canizares
Director, Center for Space Research
Massachusetts Institute of Technology

Mr. Steve Cox
Lead Communications Engineer
MITRE

Dr. Gary A. Federici
Director, Information Operations and Warfare
Center for Naval Analyses

Mr. Thurman (Rich) Haas
Principal Director, National Systems Engineering and Architecture Directorate
The Aerospace Corporation

Lt Gen John B. Hall, Jr., USAF (Ret)
Private Consultant

Dr. Barry M. Leiner
Director
Research Institute for Advanced Computer Science

Lt Col Russel M. Mayes
Chief, Airborne Communications
AFCIC/SYOA

Col John J. Murphy, Jr., USAF (Ret)
Staff Principal Analyst
Aerospace C^2 & ISR Center (ARINC)

Dr. Michael P. Shatz
Leader, Advance Systems Concepts Group
M.I.T. Lincoln Laboratory

Executive Officer: Capt Cristina Huerta, AFRL/VASM
Technical Writer: Maj David E. Bossert, USAFA

(This Page Intentionally Left Blank)

Chapter 4
Report of the Technologies Panel
Technology Investment for Future Capabilities

4.1 Introduction

The current generation of Air Force command and control (C^2) systems is built on a base of commercial technology, customized for military functionality. For example, the Theater Battle Management Core System (TBMCS) uses a commercial database (Oracle) as its core with special-purpose military applications riding on this core. Because of the significant technology development investment being made each year by the commercial software industry (over $1 billion by Oracle alone), commercial advances in information systems are growing at an accelerated rate. This situation will enable the Air Force to rapidly field new military information system capabilities, such as the Joint Battlespace InfoSphere (JBI), but will also place significant challenges on technology deployment within the Air Force's C^2 structure, simply because of the rate of change of technology. As an example, Oracle's internal cycle time from product development to product introduction is normally within a 12-month window. The Department of Defense (DoD) acquisition process constrains military C^2 systems to a significantly longer development cycle, resulting in the deployment of systems that are often built on already obsolete core products. For example, the current release of TBMCS uses a version of the Oracle database management system that is over a 100 minor revisions behind the current commercial release.

Due to the large-scale investment in information systems technology by commercial vendors, technology, for the most part, is not a barrier to development of Air Force C^2 systems. In this chapter an assessment has been made of the available technologies relevant to the C^2 intelligence, surveillance, and reconnaissance (C^2ISR) mission.

Perhaps the major challenge the Air Force faces is how to leverage the information system revolution, fueled by e-commerce, and transition new capabilities into Air Force operations on a fast time-line. For the first time since World War II, the Air Force lags behind the civil community in application of new—mostly information—technologies and inventions. The Air Force has no shortage of good ideas on how to apply technology to solving current problems. There is a growing sense of frustration, however, among the operational and development community on how to bring good ideas into the operating environment. Very little of the C^2-related technology developed by the Air Force Research Laboratories (AFRL), from the Defense Advanced Research Projects Agency (DARPA), or from the Joint Expeditionary Force Experiment (JEFX) experiments has yet transitioned into operational C^2 programs. In our recommendations we have included a commentary on how the technology transition process could be put on a fast-track to speed technology deployments that can improve C^2ISR operations.

Leveraging the information technology revolution, which is fueled by e-commerce, to enhance C^2ISR operations will require the Air Force to consider new sources for technology. Historically all major C^2ISR systems have been developed using a prime integration contractor. In our recommendations we have also addressed how the Air Force can benefit by reaching out to other technology development sources to speed the development and deployment of next-generation C^2ISR capabilities.

4.2 Approach and Visits

The approach selected by the panel for evaluating the availability of suitable technologies for achieving C^2 dominance was to request input on relevant technology efforts from technology leaders in industry (commercial and defense), from universities and from government research facilities including AFRL, DARPA, the National Reconnaissance Office (NRO), the Defense Information Systems Agency (DISA), and the other Services. Input was also provided on operational technology needs by the Aerospace C^2 Intelligence, Surveillance, and Reconnaissance Center (AC2ISRC) and current C^2 programs by the Electronic Systems Center (ESC). Finally, the Technology Panel membership was selected to provide a breadth of expertise across the technology areas deemed to be most critical to meet the Air Force's near-term and longer-term C^2 needs. Table 4-1 lists the organizations and facilities visited during the course of the study.

Table 4-1. *Technology Panel Visits*

Technology Panel Visits

Hurlbert Field — **20-21 March**
AF C2 Vision, Approach & Progress; Maj Gen Perryman
Roles & Contributions of ESC; Lt Gen Kenne
C2 as a Weapon System; Mr. Barringer
Battle Management From Joint STARS-Past & Future; Col Lindsley
Past, Present & Future Contributions of the AFC2TIG; Col Carr
USAF C2 Acquisition; Brig Gen Obering
C2 Battlelab Process, Accomplishment & Plans; Maj Swaney
JEFX 2000; Col Carr

Langley/AFC2ISR — **10-11 April**
ACC Lessons Learned In Operation Allied Force; Maj Hampton
AOC as a Weapon System; Col Joe May
AC2ISRC C2 & ISR 02 POM Campaign Plan 2000; Col Wayne Ranne
Managing the C2ISR Enterprise; Lt Col Joe Martin
Tactical Data Links USAF Interests and Way Ahead; Lt Col Mike Balog
Bridging The Gap: Operational To Tactical Art; Col Steve Callicutt
Distributed Common Ground System Program Overview; Mr. Donald Walker
Global Information Grid for the Warfighter; Col Jack Fellows
ISR Battle Management (ISRBM) Tool Demonstration Update; Lt Col Ginny Tonnesson
Air Force Experimentation; Lt Col Skip Liepman
Kosovo Lessons Learned; Gen John P. Jumper
Theater Battle Management Core System; Lt Col Kevin Damato
Time Critical Targeting & Real Time Information In The Cockpit; Lt Col David Jones
The Limitations of Doctrine; Gen John P. Jumper

NRO/DARPA — **16-17 May**
NRO Strategic Thrusts Integration Program Strategy; Maj Gen Dickman
Corporate System Engineering Function; Mr. Broadwater
Deputy Director for Military Support Perspective; Brig Gen Crawford
EMIT Perspective; Brig Gen Sover
Future System Perspective; Mr. Roche
Communications Perspective; RADM Fisher
SIGINT Perspective; Mr. Fitzgerald
Information Support Strategy; Mr. Mahen
Airbourne Overhead Interoperability Office Perspective; Col Wheeler
Strategy Gaming and Experimentation; Mr. Hernandez
Kosovo Lessons Learned; Col Gill
NRO Analysis Center Studies; Col Jones
Collection Concept Development Center; Mr. Gibson
DDB; Dr Mulari

Langley/Fusion Briefings — **23-25 May**

Rome Labs/ESC — **12-15 June**
IF Overview; Mr. John Graniero
Global Awareness Overview; Mr. John McNamara
Adaptive Sensor Fusion; Mr. Mike Hinman
Multiplatform MTE fusion; Mr. Jon Jones
GMTE - Ground Moving Target Exploitation; Lab Mr. Brian O'Hern
Dynamic Data Base; Mr. Pat McCabe
BROADSWORD; Dr. John Salerno
Joint Targeting Toolbox; Mr. Joe Palermo
Targets Under Trees (TUT); Mr. Ed Zelnio
DP&E Overview; Dr. Nort Fowler
Joint Battlespace Infosphere (JBI); Mr. Rick Metzger
Effects Based Operations; Mr. Dan Fayette/Dr. Lemmer
Intelligent Agents; Mr. Jamie Lawton
JEFX Activities; Maj Bob Marmelstein
SOF Plan Active Templates; Mr. Dale Richards
Sensor-Decision Maker-Shooter; Mr. Ken Trumble/Derryl Williams
Datawall; Mr. Pete Jedrysik/Lt Quant
GIE Overview; Dr. Warren Debany
Link-16; Mr. Mark Minges
SATCOM/CDL Activities; Mr. Walter Hartman
Airborne Communications (Node and Relay); Mr. Richard Hinman
MEMS/Ultracomm; Mr. Paul Ratazzi

Langley/ISR Briefings — **21-22 June**

SPAWAR/SWC — **26-28 June**
Center Overview/Vision Brief/Command Center of the Future (CCOF); Tom Kaye
Commander in Chief for the 21st Century; Tom Tiernan
Global Command and Control System; Jack Gerrard
Cognitive Technologies; Ken Kaufman
Strategic Decision Making Under Stress; Guy Leonard
Distributed Collaboration; Lorraine Duffy
Horizontal Integration and S&T Technology Integration; Don Johnson
Information Operations Center of the Future; Lee Zimmerman
Information Assurance Experimentation; Christine St Clair
Tactical Digital Information Links (TADILS); Janet Bailey
Common Data Link Management System; Janet Bailey
TADILS Foreign Material Sales (FMS); Greg Lawrence
Distributed Engineering Plant (DEP); Dave Andersen
Real Time Execution Decision Support (REDS); John Mc Donell
Automated Communications Management System (ACMS); Sally Norvell
Location of GPS Interference; Fernando Escobar

Summer Study Final Session — **10-21 July**
Oracle Corporation; Mike Lennon
Sun Microsystems, JavaSoft; Timothy Lindholm
TBMCS Briefing; Mike Charron, Rizwan Jaka, Howard Able

4.3 Findings and Discussions

The Air Force vision of global vigilance, reach, and power requires assured decision dominance over adversaries. The Air Force has committed to strengthen the ability of commanders to command and control aerospace forces to achieve and maintain this dominance. The opportunity exists to harvest a rich and diverse array of technologies, systems, and services to substantially enhance the ability of the Air Force to establish and maintain this essential, dominant C^2 capability. Figure 4-1 summarizes the availability of technologies either from commercial or government sources, for providing key capabilities to achieve C^2 dominance. Figure 4-1 also indicates the panel's assessment of how well available technologies are being exploited in Air Force C^2 systems. The rationale behind this assessment is included in the following sections for each key capability area considered.

Technologies	COTS Available	GOTS Available	C^2 Exploitation
Dynamic Planning and Execution	Y	G	Y
Connected, Survivable, Reliable Communications	G	Y	Y
Information Fusion	Y	Y	R
Information Assurance	Y	Y	Y
Information Management	G	Y	Y
Human-Machine Interaction	G	Y	R
Enterprise Systems Engineering	G	R	R
Green: **Some Ready** **Yellow**: **Future Potential** **Red**: **Not Yet**			

Figure 4-1. *Available Technologies*

4.3.1 Dynamic Planning and Execution

Implementation of dynamic planning and execution (DP&E) requires a shift in C^2 focus from scheduling systems to planning systems. These planning capabilities must accommodate the ever-present dynamic and uncertain nature of active operations. Some of the dynamic tasking requirements associated with time-critical targeting are described in Appendix 4D.[13] These include dynamic tasking of both sensors and shooters.

DP&E will require changing to interactive, adaptive, dynamic, and closed-loop processes as opposed to the open-loop, finite-time-horizon planning approach used in earlier C^2 systems.

[13] Appendix 4D can be found at the end of this Volume.

Many of the principles developed for use in dynamic control system design can be applied in developing this process.

Achieving C^2 dominance also requires maintaining an evaluation of the opportunity cost associated with real-time reallocation of resources. The dynamic nature of this approach also requires that the impact of the dynamic nature of the environment (for example, weather) be included in this continuous planning process. In the following sections, our assessment of available technologies is provided along with our assessment of how effectively relevant technologies are currently being deployed within Air Force C^2 systems.

4.3.1.1 Commercial Off-the-Shelf (COTS)

Examples of commercial decision-making tools that appear applicable to many DP&E situations include tools used in banking and finance as well as airline and package-delivery scheduling and corporate planning. In most cases, however, the military decision-making tasks are more demanding and complex than their civilian counterparts in the number of degrees of freedom, the scale of the tasks, the temporal dynamics of the environment, the intensity of adversarial engagement, and the impact of the outcome. As a result, few COTS technology solutions are readily applicable to the Air Force DP&E enterprise beyond general-purpose office automation suites (for example, Microsoft Office), some general-purpose analysis tools (for example, SPSS and MATLAB), and coordination facilitation tools (for example, Lotus Notes).

4.3.1.2 Government Off-the-Shelf (GOTS)

The Air Force, in concert with other DoD organizations including DARPA and the other Services, has a steady stream of DP&E research programs and prototypes in various stages of maturity. A number of these are on track for operational deployment (for example, the Worldwide Aerospace Route Planner, the Joint Defensive Planner, the Air Tasking Order Execution Management Reports, and the Joint Targeting Toolbox) and several represent emerging capabilities that need to be pushed along the pipeline. Examples include the planning and scheduling technologies embedded in the AFRL Information Directorate (AFRL/IF) products such as the Advanced Mobility Scheduler and the Campaign Assessment Tool. Still further out are capabilities deployable within several years, including the Multi-Asset Synchronizer being developed under the Advanced ISR Management program at DARPA, as well as knowledge-based planning technology emerging from DARPA's Active Templates program (run by AFRL/IF), the Attack Operations Decision Aid being developed by ESC, the AFRL Air Operations Center (AOC) Systems Status Controller and Master Caution Panel and Theater Ballistic Missile Reasoner. Many of these prototypes are to be evaluated as Category 1, 2, or 3 JEFX, or by special Major Command (MAJCOM) exercises including the Air Force Special Operations Command (AFSOC) and the Air Mobility Command (AMC).

4.3.1.3 Deployment

The deployment of promising technologies into operational use is being delayed due mainly to the lack of an environment promoting direct working relationships between the technology development community and the Air Force user community engaged in daily practice of the C^2 operational art. In isolated instances where this relationship exists (for example, AFSOC and AMC), rapid concurrent technology development and exercise consistently lead to direct insertion into the user's ongoing acquisition programs.

An effective mechanism to realize this leveraged developer-user interaction would be a sustained, pro-active C^2 center of excellence co-located with operational users engaged in the operational art with network connectivity back to the development activities at AFRL, AC2ISRC, and C^2BL. The emerging JBI Distributed Testbed will have nodes at these locations and could serve as the backbone for this connectivity. This approach would enable rapid evaluation and real-time technology steering for emerging technology while lowering barriers to innovation and insertion.

4.3.2 Connected, Survivable, Reliable Communications

Maintaining connected, survivable, reliable communications is essential to achieving C^2 dominance. The communications systems architecture must be flexible enough to benefit from current and future technologies and capabilities and must also provide seamless interoperability with numerous legacy systems, including integration and enhancement of the Link-16 system. Widespread use of bandwidth-efficient modulation, spread-spectrum capabilities, incorporation of higher frequencies, and proliferation of software radios are examples of leveraged technology insertion candidates that can enhance robustness to provide connected, survivable, reliable communications. The use of commercial communications systems and services is expected to become more widespread, and enhanced connectivity to smaller units within a more mobile Air Force and interoperability with other Service elements will remain a priority.

The scope of communications considered here includes intra-system (networked connectivity among components of the C^2 system itself) and extra-system communications from the networked elements of the system to external users (such as aircraft) and from external users (such as aircraft and intelligence sources).

4.3.2.1 COTS

The commercial sector is investing extensively in communications systems and services, many of which could be used extensively for Air Force and DoD needs. It is appropriate to recall that much of this current investment in systems and services is based on technology initially developed as a result of research funded by DoD. Examples are numerous and include networking protocols, fiber optic technologies, wireless networks, satellite communications (SATCOM), high-power amplifiers, low-noise receivers, integrated circuits, and many more. Much of the current investment is fueled by the need for greater bandwidth and is driving the installation of fiber optic networks and the development of fiber optic components, including wave division multiplexing. Wireless technology is another major area of investment. This is being driven by the expanding use of cellular systems and wireless access by a variety of personal digital assistants.

Intra-system communications support the network used by the C^2 system for internal network communications. COTS solutions exist for many of these C^2 requirements. COTS networking protocols, including Internet Protocol (IP), ATM, and SONET provide connectivity and interoperability. Commercially available security capability is sufficient to isolate C^2 networks from the secure networks they ride over (for example, secure sockets as used by TBMCS and others). Messaging standards are also available, including Extensible Markup Language (XML), which are being designed to facilitate networked data transfer between information systems.

Extra-system communications are necessary between the C^2 system and the outside world. Most of this communication traffic will be carried by direct radiated radio frequency (RF) or SATCOM links. Commercial standards for these links, including GSM-3, IS-95, and VSAT, exist and are suitable for many DoD C^2 needs.

4.3.2.2 GOTS

Current Government communications systems used to provide "anytime, anywhere robust connectivity" have generally been unique implementations of COTS solutions. GOTS standards exist primarily because the commercial standards do not take into account many unique DoD needs, including security, low probability of detection and interception, and survivability. Examples of these GOTS standards are numerous and include Link-16, TADIL-J, TADIL-B, Common Data Link, TCDL, and others.

4.3.2.3 Deployment

Deployment of commercial systems and services for satisfaction of C^2 needs will increase. It is also true that continued, sustained investment to satisfy unique C^2 mission requirements must continue. The combined commercial focus on near-term technologies and government focus on longer-term technologies has resulted in opportunities for government investment that will enable unique and unprecedented advances. A number of the most highly leveraged investment opportunities follow.

Programmable and Software Radios. This includes programmable waveforms and programmable spectrum usage. The purest form of this is the software radio, which has no conventional RF demodulator at all and thus has unprecedented flexibility in modulation and spectrum. The Joint Tactical Radio System program is developing a digital radio that will store six simultaneous pre-programmed waveforms. Once developed and in widespread usage, this technology offers the opportunity to develop and deploy new waveforms and spectrum usage algorithms to meet specific jamming and channel capacity challenges. In addition to the component technologies needing to be developed, system-level development and integration will be challenging. The ability to dynamically deploy these new waveforms and algorithms in near–real time will require the development of more adaptable software radios, appropriate transfer protocols, and supporting infrastructure and policy.

Exploiting Commercial and National Satellites. Commercial and national satellites offer the opportunity to communicate with aircraft with high bandwidth and low probability of detection. Much of the technology needed to do this has been developed, but much work remains to be done in designing apertures and systems that are more cost-effective to integrate into aircraft. Another high-value development is to design apertures and radios that are more flexible. Even though the cost of incorporating a new communications system into aircraft will inevitably remain high, this flexibility will allow us to adapt communications systems to reflect changing C^2 needs. Additional challenges remain, including system architecture and protection of information. A flexible infrastructure architecture is needed that can accommodate the specific commercial or national capabilities available in each potential area of operation. Additionally, commercial capabilities at any given point in time will vary, depending upon many factors totally out of DoD's control. Achieving this flexibility requires continuing the dialog with the national community. It is essential to add a dimension to this dialog, namely to establish a

meaningful and sustained dialog with the commercial sector to develop a current assessment of commercial systems and capabilities.

Integrated Network Architectures. This has long been a challenge: Each platform—aircraft, satellite, ship, land vehicle, and fixed structure—can be a node in a global communication grid, very much like a cellular network today. Significant issues with access control, adjudicating usage, and even priority usage of commercial systems in a national emergency all remain.

Link-16 Follow-On. Even though Link-16 will not be completely fielded for several more years, it is already an old technology. Significant enhancements are required to meet even today's requirements. Specifically, link latency must be reduced below 1 millisecond to enable new targeting technologies to be employed, the system must be made rapidly reconfigurable to allow the addition of assets during operations, and the overall throughput must be increased.

Integration With Legacy Systems. As we field new systems, we must take legacy systems into account. It is generally unaffordable to replace an entire communications infrastructure at once, due to the massive investment in legacy terminals. Thus new systems must be fielded in a way that allows continued support for older systems during an orderly transition. We need to develop more cost-effective ways to do this.

Bandwidth-Efficient Communications. Bandwidth is already limited today, and tomorrow's C^2 systems will use far more. In a bandwidth-constrained environment we need to develop new techniques for packing more data into the scarce bandwidth available. These techniques include maximizing frequency reuse (for example, systems such as the Airborne Communications Node, Large Aperture Spacecraft, Mobile User Objective System, ACeS, and THURAYA are all designed to do this), demand-access multiple-user techniques, bandwidth-on-demand systems, and bandwidth-efficient modulation techniques. Finally, exploration of trellis coding or soft-coding techniques (the best known is called Turbo-Coding) to reduce required bandwidth will be a very fertile research area.

4.3.3 Information Integration and Fusion

Combining information to estimate or predict the state of the battlespace, known as fusion (or data fusion), is still at a primitive stage. There is no consistent and meaningful definition or conceptualization of the "battlefield information state" that the fusion process is intended to estimate or identify and that must underlie any meaningful definition of the common operational picture.

While the main focus of fusion and situation and global awareness (S/GA) is upstream from the sensors that provide the raw "probes" into the battlefield, a critical role of fusion is to identify and quantify sensing shortfalls—that is, areas in which the available information is simply inadequate for the production of fused info-products of desired or required quality. The Air Force should make sure that the performance assessment portion of the main recommendation includes identifying such shortfalls, as well as the associated task of working with sensing technologists to identify options for overcoming these information shortcomings. The advantage of doing it in this manner is that the value of new sensors is assessed *in vivo*, as embedded capabilities that affect S/GA performance, rather than in isolation.

4.3.3.1 COTS

Commercial industry has developed and is continuing to develop applications to perform data mining. This involves defining metadata standards that are critical to the fusion process. Regrettably, enough differences exist between the problems being solved in the commercial world and the problem of characterizing a time-varying battlespace that there is limited applicability.

4.3.3.2 GOTS

Some existing fusion and other S/GA technologies contain needed and useful capabilities that can be fielded in the near term to provide enhanced C^2 capabilities. These need to be identified, cataloged, tested, and quantified in terms of performance and pushed along the transition pipeline and ported to the C^2 infrastructure.

Other existing fusion and other S/GA technologies are not quite as far along as the first set to be identified under S/GA-1, but *can* provide deployable capabilities within 5 years. These need to be identified, prioritized, and then acted upon. Since some of these capabilities are being developed by other organizations (such as DARPA or other Services), the "action" here must not simply involve internal Air Force activity but must also involve either working with (or making a case to) DARPA and working with other Services to develop joint capabilities.

Among the capabilities that fall into this class are the All-Source Track and Identify Fusion component of DARPA's Dynamic Database program, but there are many other possibilities to be cataloged and prioritized. Note that while the Air Force has done a very good job of working with DARPA in the past—in the area of ground moving-target indication, for example—even more can be done if the Air Force strengthens its technology transition pipeline so that, in DARPA's eyes, it becomes a reliable transition path for DARPA technology as well as a trusted source for identifying technology needs that drive future DARPA programs.

4.3.3.3 Deployment

Only systems that combine small numbers of inflexible types of data are being deployed. As more effective multi-source fusion engines become available, a substantially greater deployment funding line will be warranted.

Some fusion capabilities are already (or are on their way toward being) operational in contingency theater automated planning system or TBMCS and in systems of other Services (the All Source Analysis System, the Tactical Event Systems, and the Joint Maritime Command Information System/Global Command and Control System–Navy). In addition, emerging capabilities (at AFRL and DARPA) need to be pushed along the pipeline. To be sure, the capabilities available do not represent a final or 100 percent solution. However, they do represent important functionality and the point of departure for any enhancements. Not only should these existing capabilities be ported to the JBI infrastructure, but their capabilities need to be codified and quantified. Doing this, however, will require the development of a dearly needed discipline, essentially that of providing a "spec sheet" for capabilities. Very roughly speaking, what we have in mind here is the equivalent of the specs one finds for electronic components, which quantify the requirements or constraints each capability component has on its inputs and the resulting quality of the outputs it produces. An example here is track accuracy or continuity

as a function of measurement revisit rates, false alarm rates, detection probabilities, and range or cross-range accuracies.

As a related comment, we should point out that one of the impediments to the technology pipeline is the resistance to fielding 70 percent solutions: rather than being viewed as providing additional capability, developers are criticized for leaving out one particular additional 2 percent or another, which diverts effort from getting *some* capability out to the user and then using that as a launching point for enhancements. This represents a change in culture and values in dealing with capabilities and also points to the need for a requirements process that neither leads nor lags development and deployment.

4.3.4 Information Assurance

DISA estimates that there are 250,000 attacks on DoD computer systems every year. Some of this activity, when directed against DoD systems, might include information warfare (IW) actions to "prepare the battlefield" for future interference with U.S. activity. We can expect targeted attacks on DoD systems to increase during hostilities. Both the threat and our vulnerability will increase with increasing connectivity among military systems and to civilian networks. Thus, vulnerabilities in the networking technology or in any connected system can be exploited by anyone anywhere in the world to penetrate and corrupt DoD systems. Another source of vulnerability arises from the increased reliance on commercial products. Commercial security is neither designed nor intended to withstand IW attacks, and a large number of exploitable flaws and attacks on commonly used products are known to a wide community. Furthermore, the increased homogeneity that results from the nature of today's commercial computer system marketplace leaves DoD open to attacks that can quickly affect a large percentage of its operations. DoD also depends on vulnerable commercial infrastructures such as telephone networks that although highly reliable were not designed to withstand IW attack.

There are numerous risks to C^2 operations. Vigilance is required on the part of system designers, implementers, managers, and users to anticipate security vulnerabilities and to address them with technical or procedural means. Constant awareness that portions of the system may be compromised will help warfighters react appropriately to situations. Backup plans should be developed for the most likely compromise scenarios, and warfighters should be trained in these procedures. Some of the steps that can be taken to provide information assurance are summarized in Appendix 4D.[14]

4.3.4.1 COTS

To be affordable, Air Force C^2 systems, including protection functions, will be built largely from commercial software and hardware computing and networking components. These commercial products contain numerous security vulnerabilities, and as they are discovered, these vulnerabilities are routinely posted to frequently accessed websites (for example, Bugtraq). Attacks are developed against many of these vulnerabilities, and software tools to carry out the attacks are posted to hacker. Commercial security products are not built to withstand the strength of attack that can be expected for military systems, but to provide a degree of strength appropriate for many business operations. Known vulnerabilities in these security products, as well as attacks exploiting them, are also posted on the Web. Vendors may respond by issuing

[14] Appendix 4E can be found at the end of this Volume.

patches (which may take weeks) or correcting the problems in scheduled new product releases (which can take months), resulting in a period of exposure during which procedural workarounds must be employed to reduce risk as far as possible. Most system operators may not be aware of the discovered vulnerabilities in the products they are using or of the availability of procedural workarounds or patches.

4.3.4.2 GOTS

In recent years, DARPA and other agencies have funded research in information assurance that has resulted in some promising technologies that should be evaluated for use in Air Force C^2 systems. Examples include encrypted e-mail, secured protocols, better intrusion-detection components, digital signatures on software, early versions of wrapper generation toolkits, prototype local intrusion detectors, and a framework for coordination of intrusion detection and response. AFRL has participated in the development of many of these technologies and could be funded to evaluate them and select the most promising for maturing and transitioning into the Air Force. DARPA technologies available for such treatment are summarized in the tables included in Appendix 4D. In addition, DARPA has integrated several of these technologies in areas of prevention, detection and response, and security management for command, control, communications, computers, and intelligence information systems.

Because of the large shortfall of current security technologies relative to needs, the DoD research community is continuing to focus on several areas not being addressed by industry. These include

- Intrusion assessment to distinguish serious targeted attacks on critical systems of high concern from other attacks of lesser concern.
- Technologies for intrusion-tolerant systems, to maximize a critical system's ability to keep on providing service despite successful attack and partial system compromise. Component technologies could include intrusion detection, protocols that allow systems to react to detected events, algorithms to redirect resources to the most important tasks and whose behavior is difficult for an adversary to predict, and techniques for reconfiguring to a state not susceptible to the original attack.
- Technologies to limit an attacker's ability to carry out denial-of-service attacks.
- Technologies to allow existing and legacy systems to be retrofitted with some security and reliability functionality.

In addition to these, research is needed in areas of mobile code security, extending the capabilities of virtual private networks, and dependability. There is also a need to develop DoD-specific solutions for areas that industry is not addressing because there are no common commercial analogs—for example in the area of tactical networks.

4.3.4.3 Deployment

The high rate of release of new products and product upgrades means that at any given time there may be no common software configuration across Air Force C^2 systems. With each new product and product release comes the need to keep up to date on product vulnerabilities and fixes. In addition, policy must be generated about acceptable and safe product configurations, and these configuration mandates must be monitored and enforced across the Air Force. Failure to do so will result in unnecessary exposure to vulnerabilities. In addition, these products have many unknown vulnerabilities that will be discovered during their lifetimes. Generally, due to product

size and complexity, it is not possible to discover all vulnerabilities in advance, no matter how much testing is performed. Thus, all components must be treated as vulnerable, and systems that use these components must be designed with the premise that there may be security vulnerabilities in any system component. Even when security functionality is designed into commercial products and services, this security is generally weaker than that required for Air Force needs.

This means the Air Force must be able to design—from insecure components and services—systems that will be secure against anticipated threats. While the security research community has long recognized the need for viable approaches to building secure systems from insecure components, very little is known about how to do this, and secure system design remains an ad hoc, poorly understood discipline. The notion that it is not possible to discover all vulnerabilities and use this information to guide a protection strategy is contrary to current thinking in DoD, where the emphasis is on vulnerability discovery, so that appropriate protections can be placed to counter these vulnerabilities. This popular "vulnerability discovery" approach puts protections in place only where there are known vulnerabilities. But because there is no way that all vulnerabilities can be discovered, such an approach will leave the system unprotected from its unknown exploitable vulnerabilities, which, if discovered at all, will be discovered only during system operation throughout the lifetime of the system.

This is a dangerous situation, because an adversary may well discover and exploit some of these vulnerabilities that are still unknown to the Air Force. In fact, the situation is asymmetric, because a determined adversary can decide which part of the system it wants to manipulate or exploit, purchase the commercial products used in that part of the system, and spend many months deconstructing these products to discover vulnerabilities that can be profitably and surreptitiously exploited. While such an approach is clearly affordable by an adversary, it is not affordable as a defense, since the defender would have to perform a costly analysis for every system component, whereas the adversary can pick and choose its focus of attack.

This means that red teaming and vulnerability assessments cannot guide a protection strategy (as in "penetrate and patch"). A safer strategy is to assume that every system component contains unknown security vulnerabilities that can be exploited by an adversary. Where to place protections against such unknown vulnerabilities will depend on an analysis of the consequences of any of these unknown vulnerabilities' being exploited. In designing protections, it must also be kept in mind that the protections themselves can contain unknown exploitable vulnerabilities, so that layers of protection may be appropriate, depending on the estimated consequences of an attack.

4.3.5 Information Management

The concept of information management (IM) can be developed from Office of Management and Budget Circular A-130's definition of it as the planning, budgeting, manipulation, and control of information throughout its life cycle (for example, creation or collection, processing, dissemination, use, storage, and disposition). From this relative high-level view, five major functions of the information management system (IMS) can be derived. The IMS must implement the commander's policies for access, flow, quality of service, and security (information assurance). To implement the access and flow attributes of policy, a transport management function needs to span the communication level of the enterprise. Because many of

the information sources represent both legacy systems and services provided by other organizations, the IMS must provide data (information) transformation functions. The fourth function provides basic management of awareness, access, retrieval, delivery, and dissemination of information across multiple security environments. The last function is information assurance across all functions within the IMS.

4.3.5.1 COTS

COTS technologies exist to implement many of the C^2 IM processes, as the commercial requirements are similar to those within DoD. Operating systems such as Solaris and Windows NT, messaging languages such as XML, transfer protocols such as Transmission Control Protocol/IP, and scripting languages are available and constantly being improved. Data base applications and storage applications are widely available as well. Virtually all information management hardware (workstations, servers, storage devices) is currently COTS, and there seems little reason to change this. Commercial markets that will require the higher levels of information management services have not and may not develop.

4.3.5.2 GOTS

GOTS solutions that are being developed are generally tailored versions of COTS solutions. The premier example of this is the Defense Information Infrastructure Common Operating Environment, which consists of specific versions of COTS operating systems and applications grouped together with guaranteed compatibility and a certification process for applications. A notable exception to this rule is the DARPA IMS model, which has been partially implemented by DISA as the Information Dissemination Management (IDM) program. This IDM service has been deployed in European Command, Pacific Command, and Central Command to support introduction of the Joint Broadcast Service and the Global Broadcast System. IDM is also a key element of the JBI Wright Flyer project at ESC. The IMS is not an alternative to other services within the JBI, but provides a meta-service across the entire enterprise. As the JBI leading-edge spiral is constructed, the IMS must be the first service implemented to allow other services to be integrated as they are deployed. AC2ISRC should develop the concept for IMS and become the operational manager for IMS within the JBI leading-edge spiral

4.3.5.3 Deployment

Deployment of COTS and GOTS IM solutions tend to lag behind the state of the art. For C^2 to grow beyond small regional conflicts (Bosnia, Kosovo, etc.) and integrate global sources of information (air/space reconnaissance, air/space surveillance, logistics, weather, etc.), the Air Force must manage the access, flow, and delivery of information as an enterprise-scale activity. IM is an illusive concept. We know it keeps the Internet operating and allows delivery of e-mail anywhere in the world with just a name and an Internet service provider, and yet as the Air Force considers the development of the JBI, the role of IM is not understood, and there no agreement on definition or operational concept. The AC2ISRC should partner with DARPA, DISA, and NRO to continue the development of IMS capabilities needed to provide and manage information within the JBI. Recommendations on how to speed technology deployment into operational applications are included in Section 4.4.

4.3.6 Human-Machine Interaction

This is defined as the elements of the C^2 system that address the bi-directional interface between human and machine. Specific concerns of this interaction include handle-ability (ease of use plus portal tailoring) of the C^2 interface, synchronized collaborative operation of the hybrid (human and machine) decision support system, and a flexible command structure, wherein a commander contributes abstract reasoning to a quasi-autonomous decision system and can drill down if required or defer if desired.

To clarify, a decision support system with flexible command structure is intended to harness the analytical processing capabilities of autonomous systems to present the commander with a rational plan for actuation. If necessary, the execution of planning can become transparent to the human being—that is, humans can remove themselves from the C^2 loop after providing an abstract objective (the art of command) while the machine determines course of action (the science of control). The human can then be re-injected at any point in the C^2 hierarchy if desired. For example, human participation may be appropriate in circumstances where time-consuming measured reasoning can be accommodated, or even where instinctual-type (assess-react) behavior is required, while autonomous decision execution may be used in situations where learned (if-then) or analytically optimal decisions provide rapid response.

Given decision making in a centralized or distributed context, distribution of both status and command intent must be considered throughout the hybrid C^2 system. These operations should also occur in a manner that allows synchronization of executed events in time, space, and purpose.

Furthermore, to accommodate varying styles of command, the interface from human to machine can be portal-tailored to individual preferences. The individualized interfaces should, however, be based on a common functionality to avoid disrupting system stability in pursuit of system performance.

4.3.6.1 COTS

Several technologies are available for leverage in the human-machine interaction element of C^2. Relevant commercial technologies available for near-term application include automated speech recognition for transparent interface and 3D audio, separating voices in physical space for seamless identification of decision actors. Commercial technologies available for future application include untethered C^2 for wireless interface, large-screen seamless projection, and flat panel displays (see Chapter 5).

4.3.6.2 GOTS

Government technology efforts have seeded a number of cited commercial technologies, but GOTS is extremely limited in terms of existing and available technologies for C^2 application. More specifically, we believe that Air Force recognition of human-machine interaction as a technology area for C^2 investment is essentially absent. Certainly the importance of training is recognized. However, there are very important issues well beyond training that are barely articulated and for which capabilities are either severely inadequate or completely missing.

4.3.6.3 Deployment

Although COTS technologies are available for translation to government systems, very few have been exploited for operational deployment. This inadequacy is manifested in the functioning of today's AOC, which operates in an ad hoc fashion based on a decision cycle with many humans in the loop. As with many high-performance systems, the human has here become a limiting factor in C^2 due to constrained reaction times. Unfortunately, it is not possible to increase human capabilities in the loop by increasing the number of humans involved—the human being is not scaleable. In the presence of an increasingly high operations tempo and increasingly high-performance mixed-autonomy systems, the decision cycle has become vulnerable to lack of coordination and disintegration. To maintain both system stability and performance, future C^2 must consider the human-machine interaction a priori in terms of interface usability, synchronized hybrid operations, and flexible command support.

4.3.7 Enterprise Systems Engineering

Enterprise systems engineering is the set of integrated processes and resources that enable organizations to effectively, rapidly, and transparently perform their missions across functions and, where necessary, across organizational boundaries. There are three aspects of enterprise systems: First is the set of automated applications for the end; these support the operations the end user or customer wishes to perform. Second is the automated integration of these applications into the business processes, transactions, and analyses of the enterprise providing products. Third is integrated information sharing across and management of supply network resources and organizations.

A five-layer business model to guide this process is summarized by the following steps:

- **Vision:** What the result will be of the effort—how the effort will positively affect the entire business mission, under what (emerging) conditions.
- **Business model or value proposition:** How the system and practices that it helps implement will add value toward achieving the vision.
- **Strategy:** What steps, aspects, or priorities guide the development and implementation.
- **Business (operational) process and rules:** What re-engineered processes will be embodied in and facilitated by the information system, and what rules apply (access to information or services, responsibilities, authorities, etc.).
- **Organizational design:** What new roles, activities, interactions, organizational forms, and practices are required to carry out the vision and business models and to support and evolve the new information environment.

4.3.7.1 COTS

The best models for the most relevant dynamics and functionality can be found in e-enabled business: e-commerce and business-to-business enterprises. We have specific examples in industry where systems have been constructed as proprietary systems over private networks, and we are beginning to see many examples where these systems are integrated using COTS components and open standards for data interoperability communicating over the Internet. The COTS components are typically selected and integrated based on an explicit value proposition for which the components and the enterprise functionality are then customized.

These three aspects of enterprise systems engineering enable the e-business to supply customized goods and services to users on an optimized timeline, as well as to optimize processes and inventory across the entire supply network (sometimes called a value net). The three key technical features that make up the aspects are (1) process re-engineering to optimize throughput, responsiveness, and performance of the value net; (2) data and metadata interoperability across the network (typically using XML and mapping tools), which may be provided in real time or as aggregated data or reports; and (3) automated tools to customize presentation of data and customize processes offered to the customer, based on underlying business rules.

Three things enable the technical side of enterprise systems: reengineered business processes, support of these processes with customizable software components, and formal data interoperability. Process re-engineering within the retail organization and across the value net is performed to optimize throughput, responsiveness, and performance of the value net. Data and metadata interoperability across the network (typically using XML and mapping tools to translate among data dictionaries) supports data sharing, which may be provided in real time or as aggregated data or reports. Finally, automated tools must be developed to customize the presentation of data and the processes offered to the customer, based on underlying business rules.

A classic example of enterprise systems engineering with a customer portal web presence can be found at Amazon.com. Walmart with its anticipatory and collaborative planning functionality, and General Electric with its proprietary back-end value net integration systems, are long-standing examples of enterprise system engineering in traditional businesses. They have been joined by Ford and International Harvester, among others, which are using web-enabled back end business integration.

4.3.7.2 GOTS

An enterprise system for C^2 would enable the rapid initial preparation (predictive battlespace analysis), strategy, planning and execution, and would support rapid replanning and time-critical targeting. Although there are examples of integration of functionality within some DoD organizations, and common platforms with shared applications, we could discover no true enterprise systems engineering efforts that would provide a basis for development of a C^2 enterprise system. Although elements of functionality that are useful in the C^2 mission have been identified and may soon be available (elements in TBMCS, for instance), there is no true componentization of functionality, no interoperable data or metadata standards, and insufficient capture and characterization of operational processes. There has been little or no cross-organizational enterprise process analysis and engineering, or cross-organizational data interoperability development. An enterprise system enables the seamless coordination of processes across organizational or functional units to achieve an enterprise goal.

4.3.7.3 Deployment

The approach of choice clearly is to use COTS and build to a set of open commercial standards. However, COTS, middleware, and open standards are only a beginning. The most flexible and robust approach to creating an open architecture is a layered approach, where a high degree of platform independence and component autonomy can be achieved, in contrast to a "Microsoft strategy," which tightly couples functionality from operating system through presentation technology. An architecture strategy must be developed to support and unify the spiral

development process and to guide implementation choices. Flexibility, expandability, and the rapid incorporation of new functionality are best served by a composable component services-based architecture using COTS and organizing around commercial component and web standards—Java, Hypertext Markup Language (HTML), XML, and standard wrapping technologies. One trap that should be avoided is the use of conventional system integrator approaches that tie operations and maintenance (O&M) to a custom code base not maintainable by multiple vendors.

A final pitfall to avoid is the practice of regarding legacy systems as the foundation for future architectural choices—that is, allowing existing system architectures to dominate the evolution of the future system, pointing to the sunk costs as justification. Although legacy system functionality need not be discarded, the new architecture should be developed based on supporting desired C^2 processes and performance, flexibility, and evolvability criteria, and the architectural strategy and plan should focus on adapting legacy functionality into the new plan, not vice versa. If an architectural strategy is built around legacy systems and old acquisition and software practices, none of the point technologies (HTML, Java, XML) or spiral development strategies will achieve the intended effect: A robust, easy to use, evolvable, cost-effective, reliable system that is amenable to rapid technology insertion.

There are many obvious barriers to successfully implementing and deploying an enterprise system. Business has typically faced similar challenges. What enabled business organizations to move to this collaborative, enterprise-wide, cross-organizational information system was the realization that it was of mutual benefit and was necessary to accomplish the commercial mission. Collaboration and interoperability were driven by the re-engineering of specific processes, not by a mandate to do everything the same way. If we organize our efforts around the desired C^2 scenarios and experimentation with new ways of doing business, it will provide an operational grounding and definable consequences for eliminating these barriers.

4.4 Recommendations

The consensus of the study is that many of the technologies exist which are needed to build the JBI and to provide the new capabilities desired to enhance C^2 operations. Many of the barriers to moving forward and leveraging this technology base are process or institutional in nature rather than technical. Many of our recommendations therefore focus on identifying on how to speed technology deployment into the Air Force. In the following sections we describe changes recommended to accelerate the technology transition process and better leverage the commercial and government research and development (R&D) investment to provide new C^2 capabilities.

4.4.1 Faster Technology Deployment Through Spiral Development

The Air Force has elected to move to a spiral development process in support of evolutionary acquisition for C^2 systems.[15] This instruction encompasses all system acquisition life-cycle activities of C^2 systems, existing or planned, from an initial idea or technological opportunity through fielding and sustainment.

One of the major benefits of a spiral development process over a classic waterfall development process is that it does not presume that the requirements are knowable in advance of

[15] Air Force Instruction 63-123, "*Evolutionary Acquisition For C^2 Systems.*"

implementation. An example of this paradigm, for new user-interactive systems, is known as the IKIWISI syndrome. When asked for their required screen layout for a new decision-support system, users will generally say, “I can’t tell you, but I’ll know it when I see it” (IKIWISI). In such cases, a concurrent prototyping/requirements/architecture approach is needed, and spiral development, rather than waterfall development, processes should be used.

In January 2000, the Air Force Instruction (AFI) 63-123 required the use of spiral development for C^2 systems.[16] It created a hybrid spiral process that fits (uncomfortably) into the DoD 5001 and 5002 series of regulations. Despite the fact that this instruction is too new for any program to have executed under it, it is clear that while the use of spiral development is the correct approach, our understanding and direction today need some refinement.

We need to stimulate industry development of a standard for spiral development. The February 2000 Joint Symposium on Spiral Development called for such a standard, and Government participation would accelerate the process. By moving from standardization (a process owned and mandated by the Air Force) to mandatory compliance with a flexible standard the Air Force can reap many benefits. Once industry has created this standard, AFI 63-123 can be greatly simplified, and discuss only how to fit spiral development into the acquisition process.

The role of cost as an independent variable (CAIV) in spiral development must be emphasized. Funding timelines make dynamic reallocation difficult. In this environment each spiral increment is unlikely to receive funding directly commensurate with the desired accomplishments of that increment. After determining the desired level of risk reduction and functional addition ideal for a phase, CAIV processes are essential to determining how much of each should actually be done. Learning how best to apply CAIV processes to spiral development is an essential task that should be done by a Government-industry team.

We must define critical interfaces and elements of the user interface with considerable rigor in advance. These are the portions that affect other developments and the entire training process. We must allow these elements to evolve slowly and with a great deal of thought to the impacts to users and other systems and allow all other aspects of the architecture to evolve freely from spiral to spiral.

4.4.2 Move to Procurement Through Concept of Operations (CONOPS)

The Air Force is slow to incorporate new information technologies into C^2 systems. One of the reasons for the delay is that procurement of information technology (IT) systems proceeds through the same requirements process as for purchasing an airplane or a ground vehicle. The idea of developing commercial systems by satisfying detailed requirements was discarded long ago by the business community. Rapid development of new applications by commercial industry is done on the basis of a stated operational need and through close collaboration between developer and user.

The Air Force analog to procurement from need is procurement through CONOPS. Usually, suggestions for new capabilities result in a CONOPS. It should be possible to procure a system to provide needed capabilities by simply replacing multipage requirements documents with a CONOPS document. The reduction of needs to requirements is a process that frequently results

[16] Air Force Instruction 63-123, *Evolutionary Acquisition for C^2 Systems*.

in errors than are reflected in the final product. After all, what is truly required is a capability, not the satisfaction of a formal process.

It will be necessary to establish an evaluation group to certify that the operational capabilities have, indeed, been established. The group should be populated mostly by users of the new system but should include technologists and system developers. The group must be a hands-on user group. The integrated product team (IPT) model is not acceptable. The IPT process has become so bureaucratic that it is hardly useful in the modern world of military procurement. Membership is frequently at the wrong management level. For the CONOPS procurement method to work, the evaluation group must consist of people at the working level—that is, users and software and computer developers. Such a radical change in process may not be popular with contractors, but the purpose of the Air Force acquisition process is to provide new capabilities, not to procure new "widgets."

A CONOPS can be a simple overview of connectivity and functional nodes, or it can be a set of detailed descriptions of connections, information flows, activities, interdependencies, and timelines for a number of possible scenarios or conditions from the perspective of different user organizations. These descriptions can be represented in simulations that provide performance and flow dynamics over time. The latter version of CONOPS is the approach currently taken by AC2ISRC, and the approach that will yield data appropriate for acquisition in the spiral development model. These CONOPS provide a rich model for developers and contractors to determine performance needs, and it opens up the technical trade space and technology options to provide the capabilities needed in a timely, cost-effective fashion. The functional node representation along with the dynamic simulation allows the detection of successive gaps and bottlenecks in the process and identifies high leverage points for technology development and insertion. This approach ensures optimal, operationally significant improvement in defined processes and is far more reliable in ensuring operational capabilities than the formal requirements process.

4.4.3 Planned Divestiture for Obsolete Systems

Sustainment is a big bill to pay and a significant barrier to technology transition. During the 2002 Program Objective Memorandum, the MAJCOMs identified 240 sustainment disconnects and initiatives of nearly \$3.5 billion unfunded annual. U.S. Air Forces in Europe and the Pacific Air Forces requested a 50 percent increase in O&M across the Five-Year Defense Plan. Increase in capability, historically, is not programmed with proportional increase in support infrastructure. Much of this bill is the essential infrastructure and training needed to underpin our C^2ISR capabilities. Facing these huge bills, the MAJCOMs are often unwilling to add new capabilities, which only adds to their sustainment burden. Hence, many outstanding technologies, and the military capabilities that they enable, remain in the labs and in the industries where they were developed.

In today's budgetary environment, the only way to afford new capability is to divest of old capability. Given that the Air Force cannot pay for everything it wants, difficult decisions need to be made as to which capabilities are truly needed and which are not. Something good generally must be given up to pay for fielding something better. These decisions are very tough to make and require involvement of the most senior leadership in the Air Force and DoD. The Air Force needs to consider the current investment in C^2 and ISR—is it sufficient to carry us into

the warfare of the Information Age? This assessment should focus on overall capability, not on individual programs. A process needs to be developed in the Air Force for identifying legacy systems that are beyond their effective lifespan.

4.4.4 Timely Application of COTS

In the C^2 information technology environment, the deployed capability is usually 3 to 7 years behind the state-of-the-art technology in the commercial world. The commercial IT engine tends to turn over technology in 8- to 15-month cycles due to upgrades in software/hardware and changes to respond to market forces. The result to the military is that much of the COTS technology being deployed in C^2 systems is already outdated by the time it is delivered to the operational warfighter. There are multiple reasons why this problem exists:

- First, many IT acquisitions have used a waterfall development cycle that freezes the COTS early in the development cycle with no plan to upgrade as new releases are announced. The acquisition process has allowed contractors to modify COTS to better fit operational requirements, with the result that the capability is no longer COTS and costly upgrades are needed to add new capabilities that otherwise would have been available in the next-generation COTS product.
- There are no general plans to accommodate new releases and upgrades during development, as funds set aside to do this have proved difficult to defend.
- The COTS developer is usually forced to work through a prime integration contractor. The result of this is that the COTS developer is often not integrally involved in plans for future development, and the integration contractor is not always aware of what next-generation COTS products will be able to accomplish.

To avoid these problems in the future, the Air Force should plan to build C^2 systems, where possible, using unmodified COTS products. Enterprise licenses should be negotiated for core COTS products to facilitate their ubiquitous use operationally. Using the built-in development tools available in the current generation of IT products, many operational needs can be satisfied by distributing freeware—customized scripted programs that run on COTS applications.

4.4.5 Facilitate Science and Technology (S&T) Transition

The task of transitioning technology developed in AFRL and Battlelabs has been a primary area of concern and a constant source of frustration. While technology development always involves the failure of some efforts due to technological limitations, the process of incorporating into Air Force C^2 systems those pieces that do succeed has, for the most part, also failed. The sources of this failure range from poor communication to long, bureaucratic processes that result in technology obsolescence before new capabilities can even be deployed. While much of the Air Force's C^2 needs can be addressed by leveraging commercial technology, there are areas where focused investment is needed to develop capabilities where no commercial market analog exists (see Figure 4-1). It is essential that the Air Force and DoD's investments in these areas can rapidly transition into operational use to augment the capabilities available from COTS information systems.

The primary barrier to technology transition from the laboratories in the IT fields was perceived as being due to a lack of communication between technology developers and the actual users. This communication is essential early on in the development process to connect the technology push to the operational user pull. With the current Air Force R&D process, the communication to the laboratory of the C^2 capability needs and requirements is through multivolume documents

published by the AC2ISRC. This process is a poor substitution for establishing communication between the technologist and the operator during development. Without this connection, the technology developers are frustrated by not knowing what the users want, and the users are frustrated that the technologists cannot meet their needs. Moreover, the time spent by the technologists to track down what was meant by a specific capability need and how complex the need truly is detracts from the productive time spent on the development effort.

The consolidation of C^2 requirements by AC2ISRC is useful endeavor that can result in one-stop shopping to match a technology with a need. But often the result is the direct isolation of technologists from users and their environment, causing confusion, and a lack of user context. There needs to be a better teaming approach among the Air Force laboratories, Battlelabs, AC2ISRC, and the user community to better facilitate overall communication. Improving this communication can lead to more effective transitions of technology.

Where a good teaming relationship has existed between the laboratory and the user community, technology transition has proved to be very successful. Without this relationship, the technology transition record through the acquisition program has proved abysmal. For example, the Intelligence Division at AFRL/IF has been very successful over the past three decades by working very closely with the intelligence users to develop the requirements together and explore the space of what is possible and by developing these systems for direct insertion to the field. The current Broadsword effort at AFRL/IF is an example of spiral development where a small team of developers and users consistently worked together to produce a technology product that is fielded, meets users' capability needs, and is constantly improved with user involvement. Another example of a transition success has been the technical relationship established between AFRL/IF and AMC. While embarking on Mobility 2000, a major initiative to improve its C^2 and business practices, AMC understood that technology could not solve, but could help improve, those processes to better match the much more efficient processes found in the commercial airline industry. AMC and AFRL/IF signed a Memorandum of Agreement that established an "information technology pipeline" between IF and AMC. IF would constantly look at its tech base, consisting of GOTS development via DARPA and COTS tools to look for new solutions to the capability needs of the initiative. This resulted in the establishment of an AMC/IF Skunk Works concept and facility, where new, innovative solutions could be tried in a realistic environment. This type of "honest broker" relationship has resulted in several ongoing transitions of information technology to operational AMC systems, with spirals taking place both during and out of cycle with JEFX.

The majority of information technology funds managed by AFRL/IF are provided by DARPA as, over the years, the Air Force's S&T investment in this area has shrunk drastically. AFRL/IF has taken a portion of the dwindling Air Force S&T 6.3a funds to attempt to facilitate the transition process. This facilitation occurs by forming critical experiments and Technology Integration Experiments (TIEs), which involve an Air Force user and a specific Air Force user need. Because these are experiments, some of these TIEs fail or are dead-end engineering, while others are used as an initial technology transition spiral. The result so far is that several have transitioned to users, while others promote subsequent TIEs, therefore becoming subsequent spirals, and others have developed into entirely new technology programs.

4.4.6 Leverage New Sources of Technology for the Air Force

The Air Force's future will require the ability to rapidly respond to a changing and uncertain future mission. The current large-scale vertically integrated monolithic integration process is based on a single prime contractor and a rigid requirement process. The Air Force's ability to obtain access to innovation and emerging technologies that ensure a competitive advantage are severely restricted by this rigid acquisition model. Industry has evolved to a horizontally integrated, segmented acquisition model based on the following three principles: (1) a simple underlying architectural model based on standards, (2) an acquisition strategy based on component development that heavily leverages software reuse and existing product services due to the premium for access to talent and pressure to reduce time to market requires an acquisition strategy, (3) a business model that encourages and rewards competition, sometimes competing for the same market (in the case of the Air Force, the same mission need). These principles are now transforming the global economy.

The transformation occurring in the global economy from a highly structured sequential investment strategy to the very flexible, dynamic, rapid time-to-market new economy model places great emphasis on rapid product insertion into the marketplace. This new economy model places importance on information-based business processes and how these processes guide investment and innovation. The Air Force can exploit a parallel strategy using the spiral development process to guide the rapid development of new technical capabilities into the operational environment by following management processes similar to the new economy model.

As the Air Force moves toward the new economy model in spiral development, it will need to focus on how resources are invested by leveraging the most innovative components of industry, DARPA, university consortia, the Air Force, allies, and joint-Service laboratories and Battlelabs. Also, one of the most overlooked sources of technology innovation is the Air Force's own workforce. Modern information products are becoming more sophisticated and allow operator/users to "program" these applications using customized scripts to perform complicated, special-purpose information management tasks. With the pressures being placed on industry to produce better products more rapidly and with fewer engineering personnel, this trend can be expected to continue. This predicted transition is analogous to the change in the telephone system where technology had to be introduced to replace operator-connected calls with automatic dialing. Without this technology change, the prediction was that every person in the United States would need to become a telephone operator for the telephone system to run. Without the technology to provide user-friendly customization of complex software applications, a similar prediction would be that every person in the United States would need to become a software programmer for the e-commerce revolution to continue.

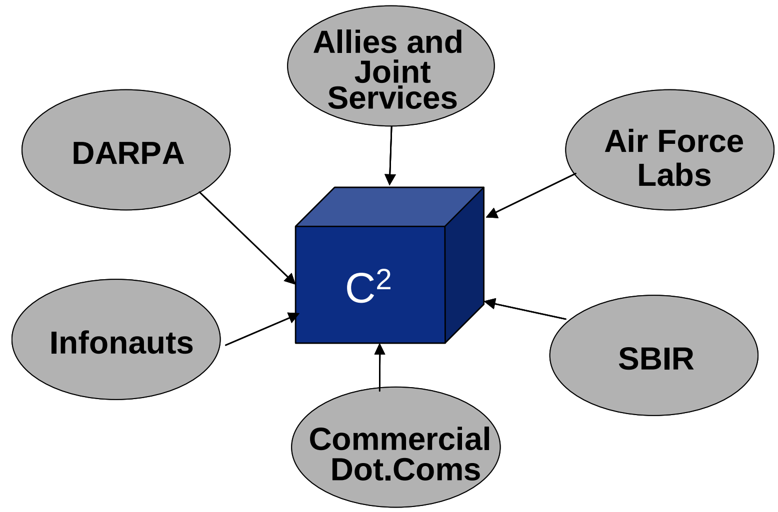


Figure 4-2. *New Sources of Technology*

The current acquisition process is geared toward large-scale procurements through a prime integration contractor familiar with the Air Force's legacy C^2ISR systems. While, for large scale systems, this approach has proved necessary, the Air Force needs to reach out to alternative technology sources to achieve the benefits of the flexible, dynamic, rapid-time-to-market new economy model in the next generation of C^2ISR systems. The technology sources we suggest to be better leveraged are shown in Figure 4-2.

4.4.6.1 Small Business Technology Sources

Much of the information revolution is being fueled by small businesses and e-commerce new starts. These are not ordinary defense contractors. The Air Force can outreach to these small innovative industries through better use of the Small Business Innovative Research (SBIR) program. Congress provided this means to gain access to these small industries with funding already set aside within the Air Force budget (6.5) for R&D. The SBIR program is conducted in three phases. The first phase provides an initial assessment of the technology, the second phase concludes with a limited demonstration of technology feasibility and maturity, and the third phase transitions technology into commercial use or into Federally funded R&D.

In creating the SBIR program, Congress created a means for the Air Force to focus an investment in innovative technology by providing resources independent of research, development, and acquisition program funding. Congress's approach was to give an incentive for small business' access to Government funding by setting aside two and a half percent of development funding to the SBIR program. In C^2, these SBIR set-aside funds are a significant R&D investment in comparison with the AFRL/IF discretionary Exploratory and Advanced Development funding, which has been declining in the area of IT.

The current management process for C^2 SBIR does not follow a central strategy coordinated with the AC2ISRC vision. The SBIR topics are nominated by AFRL and the acquisition program offices (Program Executive Offices) and the Designated Acquisition Commanders. This chaotic approach leads to few technology transitions from the SBIR investment into operational capabilities. Increased focus and technology transition would result from investing the C^2

component of the SBIR funds (those C^2 programs taxed) based on a central strategy developed and managed by the AC2ISRC. The execution of these SBIR funds should be managed by AFRL. This strategy could be used, for example, to give small business an incentive to develop and demonstrate technologies for the JBI.

If the AC2ISRC were to develop and operate a leading-edge experimental testbed (for example, CAOC-X), a large number of innovative concepts (arising from large aerospace industry, Service laboratories, and SBIR) could be evaluated. Those demonstrating utility to AC2ISRC and that were sufficiently mature would rapidly move to an operational prototype for testing and evaluation by the users. A budget should be set aside for Phase III transitions to rapidly occur from successful SBIR development efforts.

4.4.6.2 DARPA as a Technology Development Partner

DARPA is making a significantly larger investment in IT than the Air Force is. This could be better leveraged within the Air Force by re-establishing the long-standing relationship that the Air Force had previously with DARPA. Up until the past 10 years, the Air Force agenda dominated the investment strategy at DARPA. The Air Force not only provided 90 percent of the military workforce but also sent only its most competent and trusted officers to DARPA. Because DARPA possesses both a culture of innovation and a budget to support innovative solutions the rebuilding of this close relationship will be critical for the JBI.

The Air Force Technology Executive Officer should assign adequate quality personnel to DARPA to ensure that the Air Force's JBI objectives are met. DARPA is not currently part of the JBI process and yet the SAB 1998 Summer Study proposing the JBI was founded mostly on DARPA technologies. The AC2ISRC should lead an effort to define future operational concepts and technology needs for DARPA to focus the development of needed technologies. The AC2ISRC should additionally ensure that DARPA is integrated into the leading-edge spiral JBI experimental evaluation process.

4.4.6.3 University Research

Many of the emerging information technologies needed for the JBI begin in the university system. Air Force Office of Scientific Research (AFOSR) and AFRL have an ongoing research relationship with specific components of the university system for more generic technology development. Working with concepts developed by the AC2ISRC, AFOSR, and AFRL should encourage investments in university research that lead to new capabilities for the JBI. AC2ISRC should provide access to the leading-edge spiral JBI environment for experimentation and evaluation of these emerging capabilities.

4.4.6.4 Joint-Service and Allies' Laboratories

A major source of new technology and concepts for interoperability is other Service labs and our allies' laboratories. One major challenge facing the JBI is the integration of other Services and our allies into C^2 operations. The leading-edge spiral JBI provides both the platform for other Service technology demonstration, and it exploits the technology and policy issues of combined C^2 operations. AC2ISRC should develop processes and procedures to guide the development of technology that enables combined C^2 operations within the leading-edge spiral JBI. The JBI testbed should be expanded to allow joint-Service laboratories and our allies to participate in development of the JBI.

4.4.6.5 Air Force Operators as Technology Developers

Perhaps the most important source of innovation for next-generation C^2ISR systems is the "blue suit" officers and enlisted personnel in the Air Force. These people are experienced in the Air Force's mission and technology needs and represent one of the most valuable sources of mission-specific solutions. Because of frustration with the current acquisition process, many users are developing workarounds or patches using COTS tools to improve their daily productivity. Many of these "temporary" fixes have subsequently proved to perform better than their core system counterparts once they have been fielded. This occurred because of the following two essential ingredients: (1) in many cases, the operators themselves best understood the existing C^2 process they were following and how to improve it; (2) the COTS information tools used to develop the improved process included sophisticated customization capabilities allowing an essentially new software to be developed using scripts rather than raw software. Since this trend can be expected to continue, the Air Force should establish a process whereby these operator-developed systems can be adopted into the core C^2ISR systems. This will require the development of standards for documenting and sustaining these new applications. Since these have been developed using commonly used COTS products, by operators, for use by operators, the sustainment cost will likely be significantly lower than for custom-developed applications. For example, training to use a new application for an operator already familiar with the core software product and with the C^2 process being followed would likely be no harder than learning to use a new Web browser.

The Air Force, like other governmental organizations, faces the loss of quality people with information skills to opportunities outside government. The Air Force should consider creating an adjunct to AC2ISRC that gives hand-selected individuals opportunities to develop, evaluate and deploy rapid advances in the technologies needed for the JBI. The Air Force should implement a career rewards program for the most successful individuals to ensure that they continue their Air Force careers.

Appendix 4A
Technology Panel Charter

1. Identify the technologies that can enhance present and future C^2 systems with a near-term emphasis on the following capabilities:

- Network-centric operations
- Interoperability within the Air Force, with the other Services, and between legacy stovepiped systems
- Timely and effective communication

2. Provide support to the Concept and System Definition and Interoperability panels on technologies that are:

- Available for the 2005 system
- In development and which might bridge to providing JBI capabilities
- Needed before the JBI can be implemented

3. Provide recommendations to the Concept and System Definition and Interoperability panels on technologies that could be available to field in near-term operational demonstrations (for example, Expeditionary Force Experiment 2002).

4. Work with the Acquisition Panel to investigate methods for speeding transition of technology from development, experimentation, and operational demonstrations to fielded implementation.

5. Investigate COTS technologies that can be leveraged with an emphasis on near-term capabilities that could be fielded to evolve the JBI.

6. Technology areas to be investigated will include (but are not limited to)

- System and software development processes and tools
- Planning and decision making aids, models, and tools
- Communications
- Data links and message protocols
- Network architectures
- Multi-level security
- Data fusion, management, and presentation
- Geolocation and targeting

(This Page Intentionally Left Blank)

Appendix 4B
Technology Panel Membership

Dr. Alison K. Brown, Chair
President
NAVSYS Corporation

Dr. Thomas A. Brackey, Deputy Chair
Executive Director, Technical Operations
Hughes Space and Communications Company

Dr. Duane A. Adams
Vice Provost for Research
Carnegie Mellon University

Mr. Timothy M. Bonds
Analyst
The RAND Corporation

Mr. John N. Entzminger
Private Consultant

Dr. Gene H. McCall
Chief Scientist
AFSPC

Prof. Alan S. Willsky
Department of Electrical Engineering and Computer Science
Massachusetts Institute of Technology

Maj Kenneth S. Kreit
Program Manager, Large Aperture Spacecraft
National Reconnaissance Office

Advisors: Dr. Kevin B. Kreitman, Aerospace Corporation
Mr. Richard Metzger, AFRL/IF
Mr. Jay Scarano, MITRE Corporation
Maj Michael J. Estes, C^2ISR Center
Maj William Richard, SAF/AQII

Executive Officer: Maj Timothy P. Nickerson, AMC/XPX
Technical Writer: Maj Joseph E. Brouillard, USAFA/IG

(This Page Intentionally Left Blank)

Appendix 4C
Defense Information Infrastructure Common Operating Environment (DII COE)

1.1 Introduction

The Air Force is becoming increasingly dependent on using commercial software in major defense systems. Examples include the Airborne Warning and Control System and the Theater Battle Management Core System (TBMCS). The major benefit of using commercial-off-the-shelf (COTS) software is that the Air Force can leverage the huge investment being made by the private sector to develop software that is very similar if not identical to that needed by the Air Force. Furthermore, exploiting commercial software lets the Air Force stay at the leading edge of what is available. The days when the Air Force led the commercial sector in developing software-intensive systems are gone and not likely to return.

There are a series of obstacles which must be overcome in order to take advantage of COTS software. The biggest obstacle to successful commercial technology incorporation is inflexible requirements. Effective use of COTS products demands flexible requirements from the outset and a trade-off process that extends throughout the entire engineering, manufacturing, design, testing and fielding process. A second obstacle is that commercial computing and communication technology is a “moving target” that must be dealt with continuously throughout the life-cycle of the system. A major system, composed of many products developed by a number of different vendors, can be very difficult to maintain by the traditional method of periodic releases, say every 18 months. This is because the commercial products are on independent development cycles, many much shorter than the periodic release cycle. The periodic releases may introduce new functionality as well as fix bugs. A fixed 18 month release cycle means than much of the software in the system is obsolete for the bulk of the time it is in production. This can result in frustration for the users who want to take advantage of newer technology, and can be a burden for developers who must continue to build on an old technology base. This must be balanced against the risk of introducing upgrades and new products, that may introduce software errors or perturbations in the testing environment.

Commercial technology that we wish to exploit comes in many forms, including system software, applications software, appliance devices such as personal digital assistants, and development tools such as scripting languages. Complementing the commercial products are research products from organizations such as the Defense Advanced Research Projects Agency (DARPA), Air Force Research Laboratory (AFRL), ACTDs, Battle Labs and locally-developed software products which meet the needs of particular user communities. The challenge is to find a process that encourages and facilitates the use of this expanded technology base while preserving the integrity of the systems that must remain operational during the transition.

This document discusses one particular part of the infrastructure, the Defense Information Infrastructure Common Operating Environment, better known as the DII COE.

1.2 What is DII COE?

At the highest level of description, the DII COE is a creation of the Department of Defense (DoD) designed to:

- Facilitate joint system interoperability
- Improve functionality for the warfighter
- Realize savings in system life-cycle costs

At another level DII COE is:

- A reference implementation of the DoD Joint Technical Architecture (JTA)
- A software infrastructure
- An approach to facilitate integration
- An approach to improve software engineering discipline

In terms of components, DII COE is composed of:

- Operating system services (Unix, NT) and windowing (X, Motif, NT)
- Infrastructure services (printing, Web servers, communications, management services, toolkits, etc.)
- Database schemas and metadata standards
- Common support applications (office automation, message processing, etc.)
- Standard applications programming interfaces

Applications run on top of DII COE. TBMCS is such an application.

1.3 Why have a Common Operating Environment (COE)?

You might wonder if the DoD is the only entity that has a COE, and it clearly is not. Most major corporations have a COE and a software development process for their internal use. The main reason for having a COE (and the tools that support it) is to facilitate the installation, operation and maintenance of applications. The DoD COE goes a step further than most organizations, prescribing rules to ensure that applications do not interfere with each other when concurrently installed on the same piece of hardware, and supplying installation software that provides capability beyond commercial technology.

Vendors of major computing systems often provide a similar environment and support tools. For example, most PC users are familiar with a Microsoft operating system (Windows 95, 98, or NT) and many of the applications that one might choose to install (for example, Norton anti virus software or the Netscape browser) come with the tools necessary to install them on a Microsoft platform. The same is true for applications on an Apple, IBM, Dell, or Sun platform. However, the environments provided by Microsoft, Apple, and Sun are different. So are their tools, and one cannot depend on all third party software systems (for example, Norton anti virus software) to follow any particular convention for installing and de-installing their applications. Nor can one assume that the installation of a new application or a product upgrade won’t break some other application. It is a user-beware environment today.

The DII COE is built primarily using commercially available software systems. The current version is typically referred to as the COE 4.x series. COE 4.x includes Solaris 7 and 8, Oracle 8i, Windows 2000, and many other features, including more extensive use of Java. COE 5.x will include updates to the standard platforms mentioned above and real-time support such as the Lynx Operating System and real-time CORBA products. Current TBMCS, because it has been in development for several years, will be fielded on COE 3.1 for the Navy and COE 3.3 for the Air Force. COE 3.x includes Sun's Solaris 2.5.1, Oracle's 7.3.2.3 database and Microsoft's NT4, among others. COE 3.x will be in the field for several years to support TBMCS operations.

One of the key concepts in the DII COE is the Integration and Run Time Specification (I&RTS). This specifies the run time environment and informs application developers of their responsibilities if they are building applications to run on the COE. The focus is on allowing run-time integration. There is an 8 level hierarchy that describes various levels of compliance. Level 5 compliance is the near-term goal for most applications. It is commonly described as "peaceful coexistence", meaning that when an application is loaded on a platform or un-installed, it will not adversely affect any other application on the same platform.

The above description is only meant to indicate the general direction of the DII COE evolution, not a complete description by any means. This is clearly a significant undertaking for the DoD. Counting the COTS and government-off-the-shelf (GOTS) software in DII COE, there are reportedly over 1 billion lines of code. While most of this code is in the form of major commercial components (Solaris, NT, Oracle, etc.), it also represents a significant amount of GOTS software (20 million lines for the Common Operational Picture [COP] alone) and there is replicated functionality with what commercial organizations would normally supply with their products (for example, the kernel includes a common desktop and software installation tools). It is Defense Information Systems Agency's (DISA's) stated intention to get out of the kernel business and rely on commercial products as much as practical. We believe this is a good move. However, achieving and maintaining parity among the various computing platforms will remain a challenge.

1.4 TBMCS and DII COE

TBMCS is a major application that uses DII COE. TBMCS was one of the first to use the COE, and as such experienced many of the DII COE's growing pains. This points out the problem of implementing policy before the execution plan and technology are ready. It has been estimated that having to comply with DII COE cost the TBMCS program about $9 million. We are not able to establish that this cost is due to DII COE alone, or whether some of the costs are related to other factors. These could include having to segment legacy applications, modifying applications to integrate upgrades for commercial products that are part of the COE, and imposing good software engineering practices.

TBMCS will be used by both the Air Force and the Navy, and today these Services operate on different hardware bases (the Air Force on Sun hardware and the Navy on HP hardware). There is a portability issue, but at this time we do not know the extent of this as a problem.

DII COE is on an 18-24 month cycle for introducing major releases. The release cycle is managed by an Architecture Oversight Group and a Configuration Review and Control Board

that takes into account the development and fielding schedules of the major command and control (C^2) systems. The commercial products that will be used to implement the kernel, infrastructure services and common support applications are identified, baselined, and published. Programs then decide if they will use the new release as a foundation for their system development, or if they will retain an older version of DII COE for existing systems such as TBMCS. Once development has started, the program office must consciously decide whether to accept any changes to the baseline.

Establishing a new baseline is just the beginning. TBMCS must then be integrated in the new system, tested, validated and released to the field. It is likely that some of the commercial components will be 2 to 3 years old before the user ever sees the software. During that time there may have been one or more releases of the commercial software. This issue needs to be addressed—independent of DII COE.

There has been concern about the time lag between the introduction of commercial software and the inclusion as a COE component. For upgrades to software already in the COE, there is a relatively short process, typically measured in weeks. For new products, there can be a very lengthy process that can take months or even years. It is possible to treat a product that should eventually be integrated into the COE as a mission application, thus simplifying the compliance process. This concept is described later in the document.

Even when new software shows up in the COE, it may not be used by the TBMCS development community. Risk analysis is done to determine if the benefits of introducing a change to the baseline is warranted. The further along in the development and test cycle, the lower the probability that any given upgrade will be accepted, further reducing flexibility and causing the Air Force to fall even further behind the COTS world.

1.5 An Assessment of DII COE

1.5.1 Standards vs. Standardization

Standards are most effective when they formalize a set of rules or protocols that make sense and are necessary to perform a given function. In the case of the Internet, the Transmission Control Protocol/Internet Protocol protocols allow communication between computers that are made by different manufacturers, run different operating systems and may even be on different networks. These standards are simple and in widespread use. Other standards related to this study include Extensible Markup Language (XML), hypertext markup language, CORBA, etc.

Standardization, on the other hand, is a process that may mandate detailed compliance with a set of processes or rules. It some cases the use of standards alone is inadequate, and standardization is necessary. The developer of a computer system may want to ensure that subsystem developers comply with a common look and feel, follow standard documentation processes and use a common set of development and installation tools. Standardization often imposes a greater burden (in both time and cost) on those who must follow the standardization processes. The benefits of standardization must be examined in terms of their system costs.

The current DII COE process is viewed as requiring excessive standardization. Use of DII COE is mandated for all command and control, intelligence, surveillance, and reconnaissance systems. Those wishing to deviate from the process must request a waiver. For DII COE component

vendors, not only must the developer adhere to the design standards (segmentation, etc.), but there is a complex design review and compliance testing process that involves final approval from DISA. To mitigate the schedule risk associated with introducing a component into the COE, users are encouraged to initially segment and use the software as a Mission Application. This allows the users access to the application while the acquisition community executes the process of turning the software into a component. The distinction between COE components and Mission Applications is significant to developers, and is briefly described below.

Both Mission Applications and COE components require that the software be segmented and compliance tested. Segmentation is the engineering activity that makes the software available for integration. The I&RTS rules must be followed to ensure that the software will behave properly when installed on an end-user platform. Compliance testing verifies that the software has been segmented correctly—that it installs, de-installs, and can be started from the desktop. For a mission application, this is all that is required for DII COE compliance.

Software that will become a DII COE component has additional requirements that must be met. A formal requirements analysis and design review must be performed on the software. The formal requirements analysis results in the generation of a requirements traceability matrix. This allows developers to determine, at a gross level, which product will best meet their needs from a technical perspective—particularly important if there are multiple products available in a given solution space. Performance requirements are not addressed, so the developer must determine if the product will be acceptable for their application. For technology where mature standards exist and technical requirements are well defined, this process does not take long, on the order of 2-3 months. Difficulties arise and timelines are longer when attempting to componentize products related to new or immature technology. In this case, there may not be relevant standards, and technical requirements may not exist. Then, the technical requirements must be developed before the requirements analysis can be done. This can be an arduous task taking months or years to resolve.

1.5.2 Interoperability

One of the goals of the DII COE is to support interoperability. At level 5 compliance with the I&RTS, this means “peaceful coexistence”; that is, applications do not interfere with each other. What we really want is “semantic interoperability”. This means that there is a shared understanding of the meaning of a concept of data element, and hence every application will correctly interpret the data it obtains from every other application. Past efforts to establish semantic interoperability have attempted to create standard data dictionaries and to mandate compliance with a common registry of terms and data elements. This approach can be made to work for a small community over a small subject area, but it is not feasible for semantic interoperability across the entire DoD. The difficulty of this approach is illustrated by DISA’s success (or lack thereof) in defining common data elements for Global Command and Control System. To date they have achieved only partial agreement on 5 entities (representing on the order of 100 standard data elements); they reported that they have over 11,000 elements to go!

The introduction of the XML has been an important first step toward achieving interoperability at the syntactic level. Current research aims to build on the XML concepts and to extend the language to achieve semantic interoperability. If this research achieves its goals, there will be a

major opportunity to achieve semantic interoperability without imposing a requirement on users to have complete agreement on standard data elements.

One of the new technologies being developed to support semantic interoperability between systems is the DARPA Agent Markup Language (DAML). The goal of DAML, based on XML, is to provide not just machine readable, but machine understandable content for other DAML enabled software agents, programs and systems. DAML will be a semantic language that ties the information on a page to a machine-readable semantics (ontology). Language compliance will allow for military and commercial information technology communities to develop ontologies for their own use while also allowing the sharing of these ontologies between organizations. To address the adoption of DAML, DARPA is working with the World Wide Web Consortium (W3C) to insure that such technology fits within future W3C recommendations for the semantic web.

Another new technology that promotes rapid heterogeneous systems interoperability is the Agent Grid from DARPA's Control of Agent Based Systems (CoABS) program. The Agent Grid constitutes a service-based middleware which provides shared access to protocols, services, and ontologies to agents, object, and systems. The Agent Grid is built using Sun Microsystem's Jini and Java Remote Method Invocation which provides the ability for agents and systems to describe the services and information they can provide and how to use them. The grid then acts as the glue between these systems and communities of agents.

The Scientific Advisory Board believes that the combination of the CoABS grid and DAML described above will be a critical enabler for the Joint Battlespace InfoSphere (JBI), and recommends that the AFRL work closely with DARPA to make sure that these technologies are introduced to industry and transitioned into the JBI program at the earliest possible time.

1.5.3 Security

Most security requirements within the DII COE kernel are implemented using native OS capabilities. When properly configured, native OS security capabilities meet many DII COE user requirements, and there is the option of developing capabilities to meet requirements that are not satisfied by the OS. DII COE system integrators can also use COTS security solutions as mission applications, or as COE components, depending on the product, its market share, and its status with respect to the COE process. DISA has also been working with OS vendors to improve the security of their products and has implemented a process for assessing the impact of vulnerabilities identified by the Information Assurance community on DII COE products. OS patches are identified or developed and incorporated into the kernel to fix security problems as appropriate.

Security of the kernel has improved over the past several years by incorporating a fundamental change in kernel delivery. In the past, system integrators were responsible for configuring the kernel to meet their security needs. Now, the kernel is delivered pre-configured in a locked down state. Systems integrators work with Program Managers and the Designated Approval Authority to balance security risks and software integration needs. Also, the kernel undergoes considerably more security test and evaluation than in the past. Each release of the kernel undergoes a Kernel Security Assessment, the results of which are fed back into the development process, and vendors if necessary.

Finally, security is a part of the DII COE compliance and software acceptance process. There is a new security chapter in the I&RTS, adding to and/or strengthening each COE compliance level.

The process outlined above is reasonable. The real security vulnerabilities are not likely to be in the individual components of the DII COE but in the "seams" as one integrates components from multiple vendors, whether in the COE itself or as mission applications. This is an area where an overall security architecture is badly needed, where there must be particular attention to security in system testing, and where new technologies must constantly be examined for possible use in improving security and to see whether they introduce new vulnerabilities.

1.5.4 Costs, Benefits, and Metrics

We do not know what DII COE costs. Some of the costs are borne by DISA, while other costs are passed on to the Commander in Chiefs, Services and Agencies (C/S/A). The DISA costs include support for the management process, configuration management, production engineering, and software development for the kernel, the Integrated Command, Control, Communications, Computers, and Intelligence System Framework—the COP toolkit—and some of the tools. The C/S/A bear the costs for staffing working groups, sponsoring new components not already in the COE, and migrating Mission Applications to the COE. We do not know the extent of the costs borne by the C/S/As. One of the key issues has been the lack of funding to bring new capabilities into the COE. Costs are expected to be borne by the C/S/A, but they frequently do not have the funds. The lack of funding is a de facto priority system—no funding means low priority.

While the top-level goals for DII COE are to improve interoperability, improve functionality for the warfighter, and reduce life-cycle costs, there has been no effort to quantify any of these. Reports from Aerospace Command and Control, Intelligence, Surveillance, and Reconnaissance Center (AC2ISRC) indicate that they expect to spend a significant part of their funds budgeted to improve functionality on complying with DII COE. Of particular concern is the backward compatibility provided when new versions of DII COE are released. Processes which regularly evaluate the technical impact associated with changes in the DII COE and the benefits of DII COE mandates against mission impact and program costs are needed.

1.5.5 Requirements and Mandates

DII COE is mandated by the JTA. The JTA is promulgated by a memo dated 29 November 1999, and signed by the Undersecretary of Defense (Acquisition, Technology and Logistics), the Assistant Secretary of Defense (Command, Control, Communications and Intelligence), and the J6 (Director, Command, Control, Communications and Computer Systems).

Version 3.0 of the JTA states, "The DII COE, as defined in the DII COE I&RTS, is fundamental to a Joint System Architecture (JSA). In the absence of a JSA, the JTA mandates that at a minimum, all C^2, Combat Support, and Intelligence Systems supporting the Joint Task Forces and Combatant Commands will use the DII COE. All applications of a system that must be integrated into a DII platform shall be at least DII COE I&RTS level-5 compliant (software is segmented, uses DII COE Kernel, and is installed via COE tools) with a goal of achieving Level 8."

The overall requirements process takes too long and is too inflexible. Spiral development demands that a trade space exist between requirements, implementation and test/certification. If we expect the Cost as Independent Variable approach is to be successful, and any usable products are to be delivered, then we must set up an infrastructure to address the overall process. Many communities must re-think their business activities: from the budgeting and program objective memorandum'ing perspective, the test and certification view, the training approach, the deployment mechanisms, security accreditation, etc.

We must continue to improve installation and training technology. Parallel testing and certification opportunities must be exploited. Distributed configuration management is needed to allow developers access to software resources. The ability to easily perform regression testing must be in place. We must be able to fund technology initiatives as technology appears, not plan for its insertion years in the future.

Finally, the users must be an integral part of this process. This means providing a consistent user base to guide development, with the empowerment to make decisions in the requirements/implementation/testing trade space.

1.6 Recommendations

Many of the DII COE issues described above impact multiple organizations because of the joint nature of DII COE. While these recommendations are addressed to the Air Force, the actions will involve others, particularly DISA.

- **Take charge of your own destiny**. The Air Force (SAF/AQ, AC2ISRC, and ESC) must take a leadership position to steer DII COE to meet Air Force needs.
  - The Air Force should examine DII COE mandates and accept responsibility for providing waivers, where appropriate. The Designated Acquisition Authority has this authority now.
  - The Air Force should institute a process (spiral-like) to involve all affected parties in steering DII COE to meet Air Force needs. This includes balancing costs, operational, and technical needs.
  - The Air Force should ensure that the DII COE provides sufficient backward compatibility to meet Air Force needs, specifically for TBMCS.
  - The Air Force should develop the capability to experiment with emerging versions of DII COE in a testbed environment.

- **Streamline the DII COE process**. The Air Force (ESC/DI) should work with DISA to streamline the DII COE development and compliance processes. This includes:
  - Getting out of the kernel business and moving to more reliance on the commercial sector.
  - Allowing certification of Windows-based systems to be done by complying with the Microsoft Logo Program to be associated with Windows 2000 Service Pack 2. Explore similar certification arrangements for Unix-based systems.
  - Turn the execution of DII COE compliance over to the Services and/or approved companies in the private sector.

- **Incorporate new technologies into DII COE**. The Air Force should move aggressively (in conjunction with DISA) to accommodate the evolving technology base in DII COE. The goal is to avoid an excessive requirement and approval process.

- Embrace opportunities offered by web-based technologies emerging from the commercial sector (for example, World Wide Web Consortium) and the research community (for example, DARPA and Rome Labs)
- Seek alternate ways to provide interoperability by exploiting XML and by exploiting research on semantic interoperability.
- Insure that mechanisms needed to support the JBI (for example, publish and subscribe) are identified and accommodated

- **Do cost benefit analysis for DII COE**. Processes should be established which regularly evaluate the technical impact of changes to the DII COE and the benefits of DII COE mandates against the mission impact and program costs.

- **Look beyond DII COE**. The Air Force needs to ensure that the appropriate processes are in place to evolve their command and control systems with the changing commercial and technology base:
  - Move from a platform (hardware and software) to a service orientation. JBI is moving in this direction.
  - Develop a security architecture and continuously revise it as technologies and threats change.
  - Accommodate new sources of system development, including use of scripting and locally-developed software.
  - In accommodating these changes, develop processes that ensure the integrity of the systems that are to be fielded.

(This Page Intentionally Left Blank)

Continuation of Appendices to Chapter 4

Appendix Number	*Title*	*Page Number*
4D	Information Assurance	Appendices 4-3
4E	Revolution in Battlefield Awareness of Advanced Ground Moving Target Radar	Appendices 4-9

(This Page Intentionally Left Blank)

Chapter 5
Report of the People and Organization Panel

5.1 Introduction

The Air Force vision for global aerospace power is built upon a foundation of "quality people." In recognition of the critical contribution of skilled, motivated people to effective command and control (C^2), the Air Force Scientific Advisory Board (SAB) study leadership formed a team to focus specifically on "People and Organization" issues and their implications for improvement of the future Air Force theater C^2 capability. The panel was asked to address a broad range of subject matter areas, including organizational and institutional issues, personnel practices, training of C^2 specialists, and human interfaces for C^2 systems. The panel members included technical specialists from industry and academia with expertise in various aspects of human factors along with retired Air Force personnel experienced in both ground-based and airborne C^2 operations. The panel membership is listed in Appendix 5B.

Figure 5-1 illustrates the overall scope of the effort undertaken by the People and Organization Panel. As shown in the diagram, the C^2 system can be conceptualized as a combination of resources (hardware, software, and people) that must be utilized in the right combination to accomplish a mission within a particular operational environment. The panel was asked to review current Air Force practices relative to the human factors listed in Figure 5-1 and assess their impact on performance and mission-effectiveness of existing C^2 systems (see Appendix 5A for a complete description of the panel charter). The panel then formulated specific recommendations for improvements.

Organization and Institutions
- **Vision, Values, Policies, Leadership**
- **Structure, Doctrine**
- **Processes**

Personnel Practices
- **Skills Management**
- **Career Path**
- **Staffing**

Training
- **Requirements**
- **Content and Curricula**
- **Methods and Technology**

Human System Interface
- **Requirements and Standards**
- **Display and Control Media/Technology**
- **System Development and Acquisition Practices**

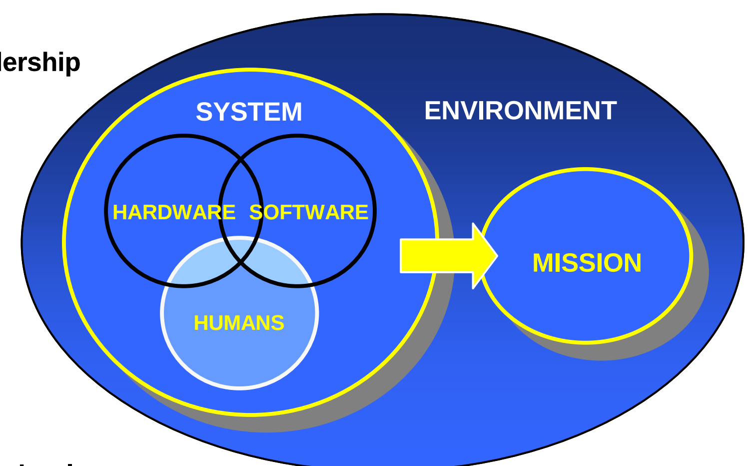


Figure 5-1. *Subject areas investigated by the People and Organization Panel*

5.2 Approach and Visits

Because of the broad scope defined by the panel charter and limited timeframe for the investigation, the collection of relevant information represented a substantial challenge for the

study team. The panel identified and contacted organizations that could provide information on current problems and challenges, ongoing initiatives, and advanced concepts related to each subject area. Organizations identified included government agencies, military agencies, commercial companies, and academic institutions. These organizations were then contacted and briefed on the purpose and scope of the study. Arrangements were made to secure relevant information by means of site visits, telephone conferences, or written reports. In most cases, data collection involved a visit to the facility to obtain briefings or demonstrations and to facilitate direct interchange with resident experts in the above subject areas. Table 5-1 shows the organizations and facilities visited during the course of the study.

Table 5-1. *Site visits completed by the People and Organization Panel*

ACC, AC2ISRC , Network Operations Security Center	**Langley AFB**
Lockheed Martin; Boeing Info. Systems	**Washington DC**
U.S. Navy; the Defense Advanced Research Projects Agency (C^2-related ATDs/ACTDs)	**Washington DC**
Air Force Fighter Weapons School/Red Flag	**Nellis AFB**
C^2 Training and Innovation Group; C^2 Battlelab	**Hurlburt Field**
93rd Air Control Wing (JointSTARS)	**Robins AFB**
Air Force Agency for Modeling and Simulation	**Orlando, FL**
AFRL Human Effectiveness Directorate	**Wright-Patterson AFB**
AFRL Information Directorate	**Rome Research Site**
Air Force Electronic Systems Center	**Hanscom AFB**
Boeing Phantom Works; Space and Communications	**Seattle, WA**
U.S. Navy Command Ship Coronado	**San Diego, CA**

5.3 Findings and Discussion

An essential prerequisite for improving Air Force C^2 is the recognition and accompanying organizational reinforcement of theater C^2 as a warfighting element on equal footing with all other combat functions. At the heart of this recognition, and built on the foundational element of "quality people" for the Air Force core competencies, is the establishment of a trained force of C^2 professionals, dedicated to operational C^2 centers. To realize the vision of C^2 as a highly integrated and effective weapons system, the human dimension in C^2 effectiveness must be addressed. The relevant human-related issues can be grouped into the following categories:

- Institutions
- Organization
- Training
- Personnel practices
- C^2 system design
- Human-system interface (HSI) technologies

A discussion of the panel findings regarding each area is presented below. Specific recommendations are provided in Section 5.4 of this report.

5.3.1 Institutions

Status, Authority, and Priorities. The absence of professional status for the "C^2 warrior" contributes to the low priority for staffing, resources, and funding for C^2 warfighting functions. As a consequence, the system defaults to improvised solutions in response to crises. Some elements of these problems are being addressed by Aerospace Command and Control, Intelligence, Surveillance, and Reconnaissance Center (AC2ISRC). However, the Center has not been vested with the comprehensive operational, budgetary, and acquisition authority to ensure that standards for C^2 operations are enforced and that acquisition and modernization are accomplished in a prioritized and consistent fashion across the full range of C^2 systems. The paradox is that many previous studies and any number of senior Air Force leaders have recognized and articulated these problems and the changes needed. However, the institutional will to fully implement change seems to be lacking.

C^2 as a Weapon System. In its entirety, a weapon system is composed of dedicated hardware, software, support logistics, facilities, personnel, doctrine, procedures, training, and various levels of command oversight. Ideally, a weapon system is defined by its mission and a specified operational capability that is described in a concept of operations (CONOPS). Historically, having the status of a "major weapon system" has served to focus priority, resources and leadership attention on the system and its enabling resources. Fundamental skill domains contributing to the effectiveness of weapon systems are often referred to as "core competencies," enhancing their value and relevance as perceived by the general population. While the C^2 mission area requires all of these same elements, it has not held the status or shared in the benefits normally accorded a traditional weapon system and its enabling competencies.

The Air Force leadership has stated the intent to treat C^2 as a "weapon system." The efforts under way to develop definitive CONOPS and operational architectures for major elements of the C^2 system represent important steps in this direction. Obtaining status as a true weapon system implies, however, that C^2 subsystems such as the Air Operations Center (AOC) will be characterized by certain key attributes that are not fully in place at present. Among these are

- Personnel staffing, skill requirements, and crew duty allocations driven by CONOPS
- Established policy for system manning levels
- Standardized doctrine and procedures for system operation, maintenance, and support
- Comprehensive, current, and standardized training publications, curricula, and methods
- Required certifications supported by regular refresher training and proficiency checks
- A system program office with overall responsibility and accountability for requirements, acquisition, and planned modernization
- A structured system engineering approach to development, testing, and configuration management

These attributes have very important implications for human effectiveness in C^2 operations. It is essential that the Air Force leadership follow through on its commitment to institutionalize C^2 and the AOC as a weapon system by fully implementing these elements of the weapon system concept.

Processes and Documentation. With regard to processes, considerable written guidance for the C^2 mission exists, but the documentation is generated through a number of independent channels

and is often inconsistent. For example, Figure 5-2 shows three different functional organizations for an AOC documented in current Air Force directives. These publications outline the functional organization of an AOC and specify from three to five major operations. Applicable documents include: Joint Publication (JP) 3-56.1 (three functional areas), Air Force Doctrine Document (AFDD) -2 (four functional areas), and Air Force Instruction (AFI) 13-1 Vol. 3 (five functional areas). These conflicting directives may inhibit standardization of the baseline AOC and have negative implications for staffing, training, and efficient transition from peacetime to wartime operations. This example also highlights a disparity between Air Force Doctrine and Joint publications. The establishment of a definitive baseline CONOPS, resolution of conflicts in directives and alignment of Air Force and Joint Doctrine should be high priorities for improvement of C^2 effectiveness.

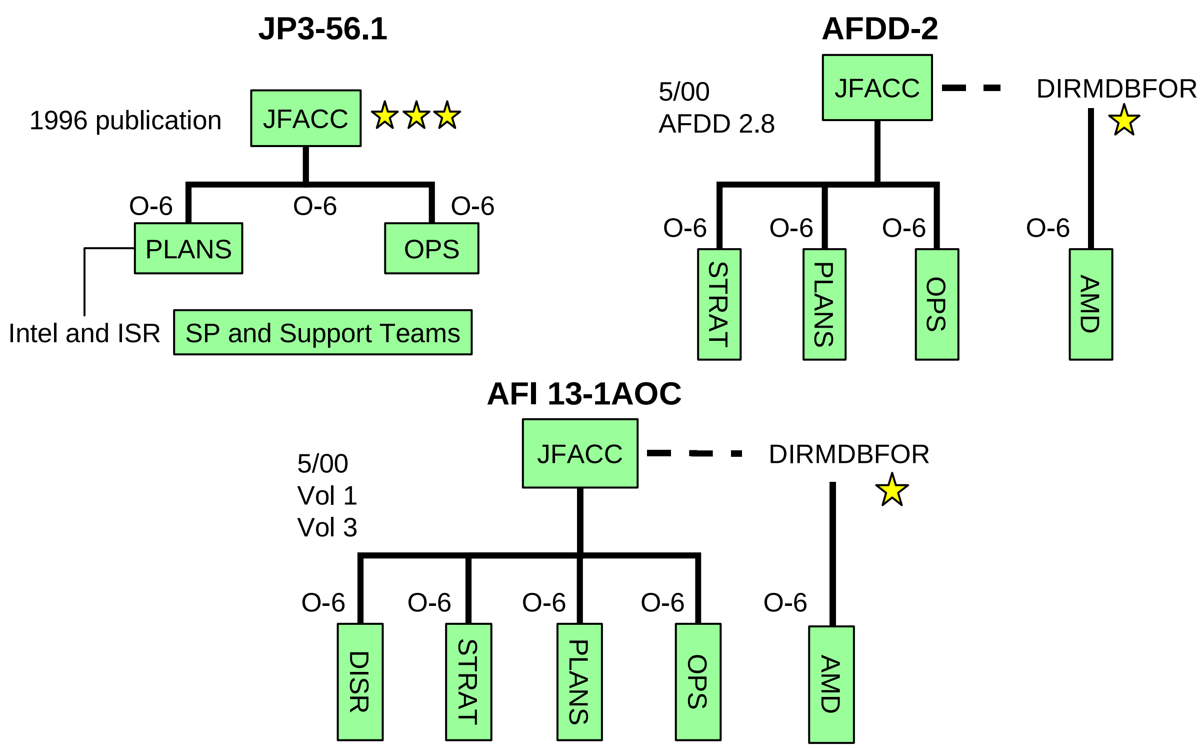


Figure 5-2. *Disparity in AOC Functional Organizations Based on Air Force Publications*[17,18,19]

Acquisition Framework. The approach used in C^2 acquisition is somewhat fragmented and could benefit from a more coherent, integrated, user-driven strategy for developing and purchasing systems. The current structure involves numerous program elements and tends to be platform- or component-centric rather than capability-centric. For this reason, stovepiped systems are prevalent in C^2, creating problems in connectivity, training, and program management. Further, many systems are not interoperable with other joint or Air Force C^2 systems, contributing to less than optimum combat effectiveness. Decisive leadership will be

[17] JP 3-56.1, "Command and Control for Joint Air Operations," 14 November 1994.
[18] AFDD-2, 17 February 2000.
[19] AFI 13-1, AOC Vol. 3, *Operational Procedures-Air Operations Center*, 1 June 1999.

required to reshape current acquisition strategies and to seek congressional support for necessary process improvements.

5.3.2 Organization

Operational Air Force C^2 weapon systems, such as the Airborne Warning and Control System (AWACS), the Joint Surveillance Target Attack System (JointSTARS), Rivet Joint, the Airborne Battlefield Command and Control Center, and the Ground Theater Air Control System are equipped with advanced sensors and have access to a large body of valuable intelligence, surveillance, and reconnaissance (ISR) information. They have extensive communications and computer processing capability integrated into their architectures to enable exploitation and dissemination of their products. Most important, however, they have a worldwide deployment mission that drives their day-to-day planning and training. They prepare for combat employment as their primary mission. These systems train with their joint and Service component counterparts in regular simulation and live events, both in the continental United States (CONUS) and in theater. An example is the deployment of JointSTARS to support Army forces at the National Training Center and AWACS involvement in the Navy's Fleet Battle Experiments. In addition, operational C^2 units run robust daily training programs for the initial qualification and upgrade of their personnel.

Only at the top level of our CONUS-based theater C^2, the AOC, are part-time operations the norm, with key personnel performing C^2 duties as an adjunct to their primary staff assignments. A review of Blue Flag lessons learned reveals shortcomings in this approach to providing C^2 warfighting capability to the Combat Air Forces. The AOC's elements, assigned to the CONUS-based numbered air forces (NAFs) are only partially staffed. At best, they train as a system annually during Blue Flag. They may augment their supported theater commander in chief (CINC) during annual training cycles, but augmentees are widely recognized to be less than knowledgeable upon arrival in theater and in need of orientation and refresher training. Standing AOCs (Operation Southern Watch, Operation Northern Watch, the Combined Aerospace Operations Center [CAOC] at Vicenza) operate with only a handful of permanent staff; additional staff rotate every 90 to 120 days. With the onset of a crisis, staffing ramps up rapidly but in an ad hoc fashion, in part because the personnel system does not support ready identification of certified personnel.

Training, manning, and modernization initiatives are all driven by organizations. The current NAF AOC lacks the structure to implement solutions. A potential solution lies in establishing standing NAF AOCs as full-fledged participants in the C^2 structure. Establishing a full-time operational AOC at a designated NAF could solve a number of C^2 problems. Most important is the placement of responsibility for training and equipping directly in the hands of a single agent. Management of this unit, its employment and tasking would become a primary responsibility for a designated NAF commander. Critical modernization would be initiated and championed by a single agent acting as principal sponsor for AOC upgrades and standardization. Coordination with the Air Staff, Electronic Systems Center, and the AC2ISRC would be managed through the tasked NAF commander.

To effectively support an Aerospace Expeditionary Forces (AEF), there must be a comparable AOC element trained and ready to deploy to support it. The C^2 NAF concept provides a management vehicle that can support the AEF while also managing the low density/high demand

(LD/HD) ISR assets. As each AEF comes into its scheduled rotation window, the NAF AOC would identify the AEF team scheduled for deployment. Qualification and upgrade training would be scheduled and managed by the personnel on alert, designated by name. The alert team would align with the alerted ISR resources to ensure effective integration of these elements from day one of any action. Current ad hoc taskings to support contingencies should be minimized and in-theater lag time reduced.

A final benefit from this concept is that each theater CINC would have fully trained and experienced C^2 professionals dedicated to support combat operations in theater. Support to standing AOCs, such as the CAOC, would be provided by designated teams. Blue Flags and annual theater exercises would be supported with personnel specifically trained in the AOC's processes and procedures.

5.3.3 Training

The Air Force does not have in place a fully trained force of C^2 professionals in sufficient numbers to respond efficiently to the demands of a major theater crisis. Air Force leaders lack the necessary training and experience to develop the full complement of essential warfighting skills, particularly at the operational level of command. The current approach to C^2 training does not support the "train the way you fight" doctrine and has not been fully integrated with the Expeditionary Aerospace Force structure and duty cycle. Resources and priorities for C^2 training are not comparable to other weapon systems, and the opportunities to gain necessary skills and experience are therefore limited. C^2 duties are not practiced routinely in peacetime and are often shared with staff assignments. These staff responsibilities often take precedence over scheduled C^2 training opportunities, since performance in these staff positions, rather than warfighting skills, is seen as the basis for promotion.

Air Force personnel assigned to other weapon systems normally experience an orderly progression of training from basic military training (Officer Training School [OTS], Reserve Officer Training Corps [ROTC], etc.), through undergraduate training (Undergraduate Navigator Training, Undergraduate Pilot Training, basic maintenance officer, etc.), to specialized training (FTU, etc.) that leads to initial qualification and mission-ready status. These efforts are managed carefully to include testing and certifications along the way and then are periodically revisited to assure currency and proficiency. Such is not the case for C^2 specialists today. Because C^2 lacks status as a weapon system, formal training is more often acquired in a less structured fashion, often through on-the-job training. This largely ad hoc approach to training produces too few senior C^2 professionals with the complete skill set and qualifications to serve effectively as mentors.

The Air Force does have in place certification requirements for C^2 specialists and training directives (AFI 13-109, Vol. I) that mandate required training. Well-designed and -administered C^2 courses and training programs are also available at Maxwell Air Force Base (AFB), Nellis AFB, and Hurlburt Field. Collectively, these programs constitute a large proportion of the necessary academic content to support a professional C^2 warrior force (see Appendix 5C for course descriptions). While a relatively complete training curriculum exists, only about 20 percent of AOC personnel have actually completed the "mandatory" training required for certification in their individual specialties. The part-time nature of C^2 assignments, combined

with staffing shortfalls and failure to fully utilize existing training opportunities, creates a downward spiraling effect—fewer opportunities supported by fewer people.

Integration of ground-based C^2 into the major weapons school exercises is lacking, as is the presence of interactive and adaptive AOC functions in Red Flag. Even the dedicated venues of Blue Flag have evolved into qualification events centered around Air Tasking Order (ATO) production instead of operational exercises that strengthen C^2 skills. This is primarily because participants are temporarily assigned on an ad hoc basis from their staff positions without the benefit of adequate preparation or daily C^2 operations. At the higher levels, the Joint Force Air Component Commander (JFACC) and AOC Director often have their first experience in these roles with the advent of a crisis. The end result is a lack of sufficient numbers of fully trained, professional C^2 leaders, at all levels, to staff and execute the warfighting functions of the AOC. Some of the specific training challenges that impact C^2 effectiveness may be summarized as follows:

- The need to prepare future C^2 leaders to move from being ATO generators and managers to become commanders of aerospace forces
- Difficulty in delivering the right training to the right person at the right time
- Limited ability and opportunity for units at all levels (air component and operational unit) to provide job qualification training and continuation training
- Lack of standardization of procedures and processes within and across major weapon systems and functional communities
- Lack of a structured method for presenting and completing standardized, accessible training products and materials at the point of delivery
- Lack of an ability to track and monitor availability and status of personnel with critical skills to support AOC and AEF operations (for example, targeting, collection management, ISR operations, airspace battle managers, SIDO and FIDO)
- Inability of personnel to attend critically needed training due to high operations tempo and personnel tempo
- Reductions in availability of centrally funded training and quotas for school slots
- Lack of an enterprise-wide skills management system to provide visibility at all levels into force readiness posture
- Lack of opportunity for daily AOC training and operations comparable to other systems and functions

Theater C^2 training and readiness could be strengthened through the development of clearer and more concise training requirements based on the C^2/AOC CONOPS and Mission-Essential Task Lists (METLs). CONOPS-driven training requirements can, in turn, provide a solid foundation for improving training content, curricula, and methods. In addition to formal training for C^2 specialists, C^2 training must be included in basic military training for all Air Force specialties. Opportunities to obtaining this foundation of basic C^2 principles include professional military education (PME) and the basic courses for various occupational specialties (for example, the maintenance officer course and initial qualification in nearly all weapons systems). These training improvements must be supported by an expanded skills tracking and management system to fully exploit their benefits (see Section 5.3.4). To enable and honor the "train as we intend to fight" doctrine, C^2 must become an integral component of nearly all Air Force operations-oriented training programs.

5.3.4 Personnel Practices

There is a widely held belief among Air Force personnel that C^2 skills and experience are not valued assets for career advancement. Indeed, there is a common perception that assignment to an AOC is a career dead end. The C^2 community suffers from the absence of a defined and viable career path, the lack of adequate rewards, and recognition for C^2 experience, and the inability to attract and retain high-quality personnel as core C^2 specialists. Personnel representing other functional domain expertise tend to avoid excursions into C^2 assignments and lack exposure to fundamental C^2 principles, further limiting the pool of talent available to augment core C^2 staff in time of crisis. To solve these problems, the Air Force must establish a recognized "C^2 warfighter" career track. Career promotions and incentives must better reward the skills and expertise of the C^2 warrior to attract and retain qualified individuals.

Skill and experience requirements for C^2 warriors and for AOC positions are not well defined or documented. In time of war, the AOC staffing problem is further compounded by difficulties in tracking skilled professionals in the current personnel system due to lack of adequate experience identifiers. Consequently, contingency-driven staffing requirements result in a pick-up solution that is slow to reach critical mass and is heavily dependent on ad hoc, on-the-job training. Today's personnel tracking system must be improved to rapidly and accurately identify personnel who have the necessary skills, experience, and certifications to staff essential AOC functions.

An expanded, enterprise-wide tracking system is needed to better manage the human resources and provide the mechanism to develop and deliver standardized, approved training to the right person at the right time. Such a system would also enable functional and force managers to gain insight into the progress, status, and level of effort across the force, including critical skill sets. It would also provide access to distributed databases, including

- Skills management (tracking certification status of critical skill sets—initial qualification training (IQT), mission qualification training (MQT), and continuation training (CT)
- Personnel management and record keeping
- Input for training curriculum development
- Virtual classroom (on-line conferencing and collaboration tools)
- Knowledge capture (digital library for reference and reuse)

Efforts are under way at the AC2ISRC to augment the personnel tracking system. Specific complementary functions offered by this expanded skills management system concept could include

- Ability to identify and validate C^2 personnel training requirements from the unit level up through the AOC level in a virtual collaborative work environment
- Ability to deliver courseware and distributed learning by means of a virtual institute or campus using Web-based technology
- Ability to document and track training accomplishments for designated active-duty and reserve component personnel to support AEF/AEW and AOC personnel requirements management
- Ability to track certifications to satisfy identified personnel qualification and certification requirements for critical skill sets

- Ability to provide automated force readiness status based on established metrics for commanders at all levels

5.3.5 C² System Design

Arguably, there is no other warfighting function where the HSI is more important than in C² because of the volume, complexity, importance and time-critical nature of decision making required. As shown in Figure 5-3, the effectiveness of the HSI is also a key element in establishing a "common operational picture," which, in turn, is essential for collaborative decision making and interoperability across organizations and platforms.

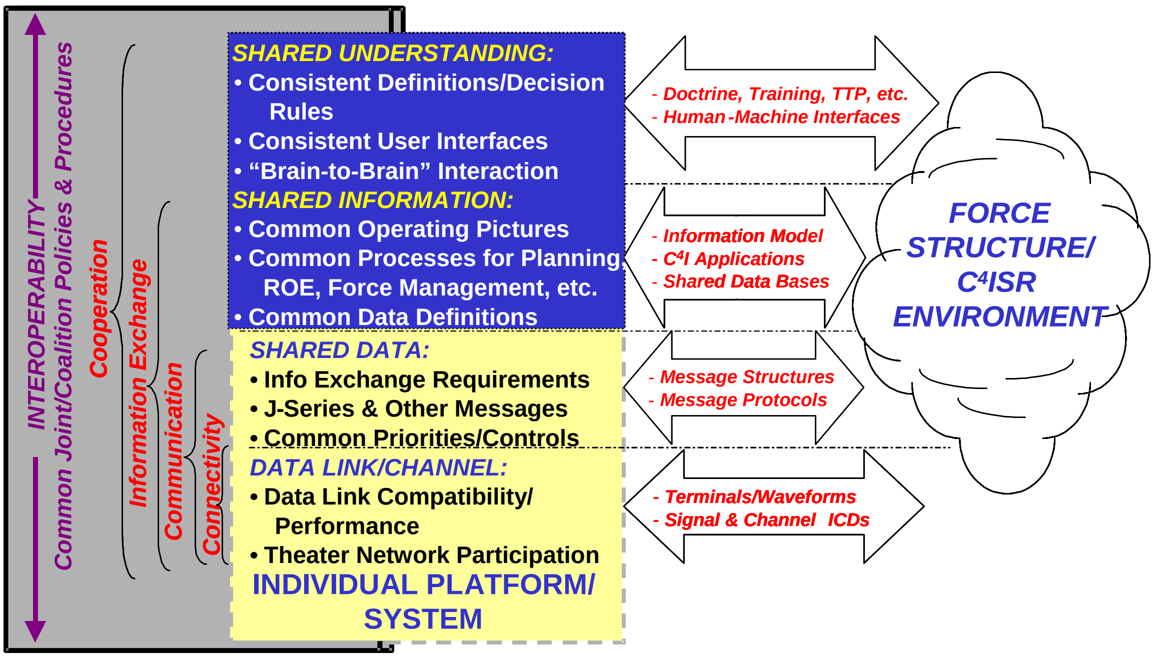


Figure 5-3. *The Human-System Interface Contribution to Interoperability*

The study team reviewed and assessed current Air Force practices for assuring effective human-system integration in acquiring and modernizing C² systems. The panel was briefed on the processes used in developing and testing of several representative airborne and ground-based systems that play key roles in theater-level battle management. These included the Theater Battle Management System (TBMCS), JointSTARS, AWACS avionics upgrades, and the Multi-Source Tactical System. The panel also received briefings or documentation on the HSI integration approach in use for current Air Force combat aircraft development and upgrade programs (for the F-22, B-1B, and C-130). The scope of these briefings and discussions included definition of HSI requirements, function allocation, crew complement and workload, HSI design, accommodation of user preferences and physical characteristics, performance metrics, and test methods.

In general, it was found that the priority assigned (and resources provided) to ensure effective HSI in C² systems is low in comparison to other weapon systems. While the Air Force has recognized the impact of HSI design on mission effectiveness of combat aircraft (for example, the F-22 and Joint Strike Fighter), there seems to be comparatively little awareness or

appreciation for the value of a well-designed human interface for the decision support systems that enable effective C^2. Some problems associated with the present Air Force approach to the HSI for C^2 systems may be summarized as follows:

- Lack of definitive CONOPS to serve as a basis for design and testing of the HSI
- Lack of a systematic process for definition of HSI requirements and metrics
- Inadequate or late involvement of operational users in system development (particularly leaders and commanders)
- Failure to establish or apply standards to ensure HSI consistency within and across systems and platforms
- Failure to fully exploit available HSI technologies and decision support tools
- Lack of definitive performance criteria for HSI effectiveness
- Insufficient human engineering capability (trained staff and facilities) within product centers for C^2 systems

While the panel found some examples of sound HSI design practices (for example, the AWACS and C-130 avionics upgrades), their application across programs has been inconsistent. In some cases, this has resulted in user interfaces that are unnecessarily complex, counter-intuitive, and/or difficult to learn. While the magnitude of the effect is difficult to estimate, these deficiencies undoubtedly have a negative impact on user workload and productivity as well as on the timeliness and accuracy of decisions and actions. These factors will in turn have negative implications for other personnel issues, such as staffing and training.

It seems clear that the Air Force could benefit substantially from the application of a more rigorous approach to the design and testing of the HSI for C^2 systems. The necessary knowledge, methods and tools are already in use in other Air Force weapon system applications. If an effective human engineering program for C^2 systems is undertaken early in the acquisition cycle, the costs of implementing it are minimal relative to the potential performance improvements.

The Office of the Secretary of the Air Force has acknowledged the need for increased emphasis on human-system integration. In a recent memorandum to the Air Force leadership, Lt Gen Stephen Plummer (SAF/AQ) stated, "Integrating the human into the early development of all Air Force acquisitions is a critical component to increasing operational effectiveness, minimizing follow-on modifications and reducing life cycle cost. The acquisition community must engage HSI more effectively early in the acquisition process."[20] While this statement represents an important first step, it is essential that the Air Force acquisition leadership put in place the necessary process, resources, and infrastructure to ensure that these goals are realized. Section 5.4.5 provides specific recommendations regarding the establishment of an improved process for human-system integration and the essential mechanisms for institutionalizing this process in the acquisition of Air Force C^2 systems.

5.3.6 Human-System Interface Technologies

The panel reviewed HSI technologies and their applications in current Air Force C^2 systems. The panel concluded that the Air Force has not fully exploited HSI technologies, automation, and

[20] Memo from SAF/AQ, Lt Gen Stephen B. Plummer, Principal Deputy Assistant Secretary of the Air Force (Acquisition), entitled "Awareness of Human Systems Integration in Air Force Acquisition," June 2000.

decision support tools that are available or under development for other applications. This finding is consistent with the conclusions reached by the Technology Panel, which found that a number of useful HSI concepts in use in the commercial sector and Department of Defense (DoD) have yet to be applied to Air Force C^2 systems (see Chapter 4). The People and Organization Panel then assessed advanced HSI technologies and concepts for potential C^2 applications. For the purposes of this study, the panel confined its assessment of HSI technologies to those available in the relatively near term (the next 5 years). The reader may also find useful a more comprehensive review of HSI technologies provided in Volume 2 of the 1999 SAB Study on the Joint Battlespace InfoSphere[21].

Table 5-2 summarizes the HSI technology assessment. The table includes concepts in use or under development in the private sector, as well as those from other DoD applications. The table also highlights some potential operating benefits to be realized and a projection of technology availability. Recommendations regarding several of the most promising HSI technology applications are described further in Section 5.4.6.

[21] SAB-TR-99-02, "Building the Joint Battlespace InfoSphere, Vol. II: Interactive Information Technologies," 17 December 1999.

Table 5-2. *Assessment of HSI Technologies for Potential* C^2 *Applications*

Technology	***Application***	***Benefits***	***Availability Date****
Controls & Displays			
Automatic speech recognition	AOC	Faster spinup time for augmentees ATO created 30 percent faster Reduced training time overall	Now, for TBMCS application 6 months for other applications
Wearable displays	AOC; training; personal gear; intelligence; operations; etc	Several wearable design options (wrist, knee, chest, around neck, on head) allow hands-free mobile display viewing See also “portable displays”	Now, for some applications (Commercial-off-the-shelf available)
Augmented reality—incorporate real-time view of battlefield and record	Intelligence; planning and wargaming; rehearsal; operations; training	Better situation awareness through synthetic enhancement of the live battlespace; reduces pattern recognition uncertainty	1 year (non-immersive)
Immersive reality	Intelligence; planning and wargaming; rehearsal; operations; training	Intuitive, high-fidelity simulation of the battlespace improves transfer of training, reduces pattern recognition uncertainty	Now, for training 3-6 years for C^2 systems
Volumetric displays	Intelligence; planning and wargaming; rehearsal; operations	Intuitive, high-fidelity representation of the battlespace reduces pattern recognition uncertainty	2-3 years for true 3-D symbols and graphics; 4-6 years for complex scene-filling true 3-D images
Stereoscopic displays	Intelligence; planning and wargaming; rehearsal; operations	Improves spatial decluttering; reduces pattern recognition uncertainty	Now
3-Audio	AOC JointSTARS AWACS	Voice communication with more people and lower rates of confusion	Now
Untethered C^2 (magnetic sensing, infrared, etc.)	AOC	Ability to use display technologies, for example, data wall, without physical constraints	4-6 years; depends on technology; see “portable displays”
Large screen seamless projection supported by a multiheaded display driver (2 to 20 display units driven as a single ultra-high resolution wall-size display system)	AOC	More flexible display configuration; ability to review more data simultaneously	1-3 years; now—knowledge wall demonstrated Aug 2000 on U.S.S. *Coronado* (10 ft tiled with 1- to 2-in. seams); seamless overlapping image tiled designs demonstrated at Honeywell, Sarnoff
Portable displays, palmtops, and tablets flexible displays	AOC Personal gear	Continued connectivity while in transit; lightweight, reconfigurable workspace options	Now—5 years with unclassified networks; 1 to 5 yrs with classified

* Technology availability date = approximate timeframe when the technology could be used in an operational system. It is assumed that initial prototypes of each technology would be deployed rapidly, with block upgrades to follow.

Technology	***Application***	***Benefits***	***Availability Date****
Controls & Displays			
Touch-sensitive displays (any size) coupled with gesture and handwriting recognition	AOC JointSTARS AWACS	Faster, more intuitive entry of graphical data; enables reprogrammable buttons; more natural collaboration with large-screen displays; provides keyboard functions for portable displays	Now
Flat panel displays; AMLCD, DMD, EL, OLED, ETC.	AOC; all C^4ISR applications; JointSTARS; AWACS, Airborne Laser	Better situation awareness, higher resolution than CRTs; lighter weight, more reliable and smaller footprint terminals; less power	1-3 years for AMLCD, DMD, EL; 3-5 years for OLED
Ultra-thin clients for client-server architecture coupled with flat panel displays	AOC JointSTARS AWACS	Lighter-weight user terminals; ease of workspace reconfiguration for custom team collaboration	Now
Biometrics	AOC	Improved security in user identification (see smart card)	2 years
Smart card user identification	AOC	Rapid, consistent logon and configuration of desktops; custom desktop and network permissions travel with user	Now
Visualization			
Perspective view of the battlespace	Planning, intelligence, and operations	Better situation awareness; reduced uncertainty in pattern recognition; supports faster, more reliable decision making	1 year
Layered imagery	Planning, intelligence, and operations	Better situation awareness; reduced uncertainty in pattern recognition; supports faster, more reliable decision making	Now–for limited map and imagery products
Logistics control and information support (LOCIS)	Wing log C^2	Customizable and adaptive dynamic user interface that allows holistic view of fused information to support wing-level operations	2 years
Realistic icons for commanders	C^2-wide	Better situation awareness; reduced uncertainty in pattern recognition; supports faster, more reliable decision making	Now

[*] Technology Availability Date = Approximate timeframe when the technology could be used in an operational system. It is assumed that initial prototypes of each technology would be deployed rapidly, with block upgrades to follow.

Technology	***Application***	***Benefits***	***Availability Date****
Decision Support Systems			
Bed-down critic	Logisticians	Faster bed down; Intelligent agents catch unintended negative consequences of plan changes	3 years
Uncertainty management using Bayesian inferences	AOC	Better decisions; ability to gauge the quality of inputs into the decision process.	3-5 years
Communication workarounds; provide or model communication routes and constraints	C^2	Interoperability; faster message dissemination, fewer missed handoffs.	4-6 years
Proactive collection plan display (predictor displays; what if's)	AOC	Faster replanning. Anticipate what will happen next in a collection plan, instead of fixating on the information that is already gathered and becoming obsolete. See the consequences of changing the collection plan.	4-6 years
Recall campaign	JFACC	Rapid dissemination of changes to an ATO, to tighten up the decision cycle during replanning—for example, if targets are destroyed, a "recall campaign" will quickly notify the affected parties.	4-6 years
Team calibration (intent) (distributed systems)	C^2	Fewer coordination surprises; support distributed teams for planning and executing together, *without* requiring lengthy video teleconferencing.	Now
Overall campaign progress	C^2	Allow planners to review the data used to estimate progress toward objectives for better replanning.	4-6 years
Work-centered decision support using intelligent agents	Air Mobility Command's Tanker Airlift Control Center	More accurate and robust decision making for airlift planning, scheduling, and operations. More timely problem identification and resolution.	Initial versions–now Advanced versions–in 2-3 years
AOC process information capture, recall, and reuse	AOC	System captures audio and video of AOC actions. This rich dataset is then indexed and correlated to screen captures of the datawall and individual workstations. This will allow "instant replay" of AOC actions and provide the data to develop improved decision support tools and C^2 training.	Now
LOCIS	Wing-level decision makers	Provides proactive decision support through the use of customizable intelligent agents monitoring critical information based on thresholds and the use of a desktop simulation to provide what-if capability.	2 years

* Technology Availability Date = Approximate timeframe when the technology could be used in an operational system. It is assumed that initial prototypes of each technology would be deployed rapidly, with block upgrades to follow.

Technology	***Application***	***Benefits***	***Availability Date****
Training Hardware/Software			
Aerospace operations/training suite initiative	C^2 for ISR	Solves latency issues surrounding C^2 responsiveness issues of ISR assets, increases situational awareness to maintain positive control over ISR assets, supports data fusion and data morphing, and integrates air and space ISR mission training and rehearsal architectures.	4-6 years
Brief/debrief system	C^2	Allows weapons directors to integrate information during distributed mission training (DMT)—C^2 brief/debrief events.	1-2 years
Human performance modeling	C^2	Improves realism of C^2 training through accurate representation of human decision-making processes.	3-5 years
MCE interface with DMT/JSAF	MCE STEs JSTEs DMT Other C^2 Platforms	• DMT and JSAF provide higher fidelity training - Realistic aircraft maneuvers - Immediate kill removal - Rapid generation and archival of training scenarios for specific instructional objectives with JSAF - Manned DMT cockpits provide communication practice - DMT provides opportunity to train as part of the combat team in the JSB - JSAF does not require simulation "drivers"; this should result in reduced manning • Training from home unit via DMT results in cost savings on temporary duty and reduced scheduling conflicts • Interface creates the potential to expand to include STEs/JSTEs and training with additional C^2 platforms via DMT • Reduced training time anticipated • Expands DMT- C^2 to include operational equipment	If existing DIS/CD2 converter can be located, immediate solution If DIS/CD2 converter has to be developed, 7 months from receipt of funding
Virtual Tactical Operations Center	Army and Air Force intelligence training	Web-based virtual environment for training C^2 warfighter and information superiority mission rehearsal scenarios	Now

* Technology Availability Date = Approximate timeframe when the technology could be used in an operational system. It is assumed that initial prototypes of each technology would be deployed rapidly, with block upgrades to follow.

5.4 Recommendations

5.4.1 Institutions

Without establishing the foundation of strong institutional value for theater C^2, most of the other actions recommended in this study will enjoy little sustained impact. Theater C^2 must be elevated in status, representation, and resources (both personnel and funding) to the levels appropriate for an essential warfighting function. The following actions are considered essential in establishing an appropriate level of visibility and priority for C^2 in the Air Force culture:

- As an initial step, the Air Force leadership should strengthen C^2 in its vision statement and long-range planning to clearly identify C^2 as the fundamental integrating function for commanding aerospace power.
- The Air Force should establish an Air Staff leadership position with the responsibility and authority to operationalize C^2, establish the AOC as a weapons system and ensure overall C^2 integration. The Air Force must define all aspects of the weapon system and assign clear responsibility for their implementation and support.
- The panel strongly supports the completion and implementation of the draft Air Force C^2 CONOPS. It is essential that the Air Force follow through on this initiative, resolve inconsistencies in current documentation, and ensure that the baseline CONOPS is used in a disciplined fashion to standardize doctrine, procedures, staffing, and training for C^2 systems.
- C^2-related program elements must be consolidated (to a minimum number) to enable more effective integration and oversight of requirements, plans, investment strategy and priorities, and interoperability standards across the full spectrum of C^2 systems.

5.4.2 Organization

The principal recommendation regarding C^2 organization is to stand up daily, under the leadership of the Air Combat Command (ACC) C^2 operational commander, the necessary forces to provide C^2 operations, training, and integration for all warfighting systems. The organizational construct is illustrated in Figure 5-4. This “standing AOC capability” would link ISR and battle management forces for daily operations and training. Strike assets would operate off an ATO or “ATO-like” order generated by the standing AOC capability and would link to such AOC entities in Flag and joint exercises. The goal is to make the transition from peace to war as seamless as possible.

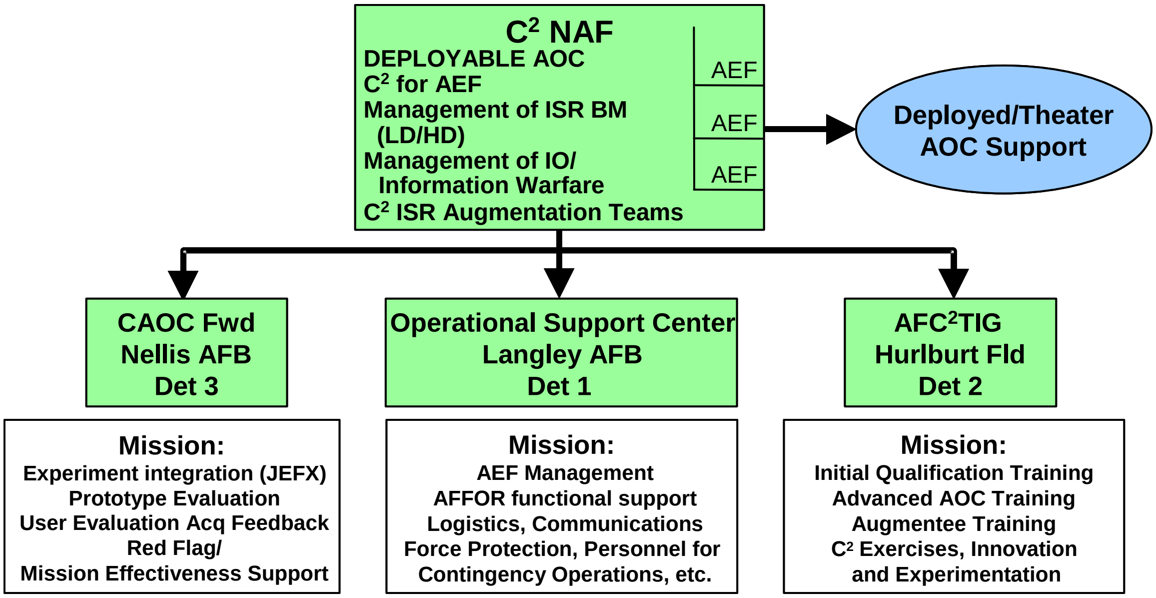


Figure 5-4. *The C^2 NAF Concept*

The intent of this organizational concept is to operationalize the CONUS AOC activities and to increase the priority of the C^2 warfighting system by making it the principal responsibility of a CONUS NAF commander. This commander should report directly to the senior ACC operational commander. The commander would provide not only principal parts of the standing AOC capability, but also management of the LD/HD C^2 and ISR assets of the information operations and information warfare resources. The C^2 NAF would be organized to align core AOC personnel in parallel with each AEF for rapid deployment if needed. Staffing and assignments would align with the functions of the AOC CONOPS, consistent with the personnel manning documents, and would rely on a mix of active-duty, reserve, guard, and civilian personnel. The C^2 NAF would also be responsible for developing AOC operational standards established for the functions defined in the AOC CONOPS. The standards would provide a baseline capability of common AOC functions while accommodating tailored aspects needed for specific regional deployments. Supporting the C^2 NAF would be the three key organizations noted above and in Figure 5-4, but in this construct they would be specifically detailed to the C^2 NAF. Other NAFs and AOCs would maintain the level of C^2 emphasis deemed necessary by their commanders.

Implementing a single NAF AOC organizes existing training, experimentation, and operational elements into a cohesive, focused organization. This essentially converts three related but stand-alone elements into a single functional, cross-supporting unit. Training at all levels would be centralized at the existing Hurlburt Field C^2 Training and Innovation Group (C^{2}TIG). The operational element at Langley AFB, previously designated as AOC Rear, becomes the daily functioning Operational Support Center. Experimentation focuses on the C^2 laboratory element at Nellis AFB executing the task of prototyping and evaluating new equipment and concepts before transition into the employment and training areas. The C^2 Battlelab and the Air Force Research Laboratory (AFRL) should work collaboratively to support this process by maturing promising technologies and demonstrating their readiness for transition. A single NAF AOC

provides the structure to coordinate actions between mutually supporting elements. It will also increase the quality of support provided to the standing theater AOCs and the AEFs.

5.4.3 Training

A critical element in moving toward "C^2 as a weapons system" is the implementation of training programs comparable to those for other weapon systems. Training requirements, curricula, and performance standards should be derived from approved CONOPS and the METL for C^2. The Air Force should establish a conventional training program for the C^2/AOC weapons systems to include the necessary qualification tests and certifications to ensure proficiency and currency. Air Force Major Commands (MAJCOMs) should be charged with ensuring compliance with all C^2 training requirements and directives. Commanders should make C^2 training accomplishment a part of normal reporting to higher authorities. Any AOC with an operational plan commitment should report training status to the applicable air component and theater CINC J-3. MAJCOM Inspectors General should inspect units responsible for C^2 and report capability (including training) based on applicable METLs.

A "standing AOC" capability should be established and charged with conducting daily operations and training missions in peacetime. ACC and Joint Forces Command should stand up the necessary forces daily to provide training and operational practice for all basic theater C^2 functions. ISR and battle management forces should link with an AOC or "AOC-like" entity for daily training. Strike assets should operate from an ATO or "ATO-like" order and link to an AOC for Flag and CINC-directed exercises. AOC(s) should be used to drive force-level CT, composite force training, exercises, advanced tactical training (Weapons School/ME), and experimentation. These training initiatives should include measurable training objectives for the appropriate level of C^2 activity. To the extent possible, actual operational links should be established with the next layer of C^2 nodes and between other represented functional activities (creating horizontal and vertical integration).

C^2 training should be tied to AEF spin-up and reconstitution training cycles. As specific rotation schedules are established for the AEFs (including LD/HD assets) and the specific training requirements for those forces are specified, two aspects of C^2 training must be included. First, the entire force (operations, support, force protection, communications, etc.) should include C^2 training and should practice the use of their respective C^2 elements daily. Second, the C^2 specialists from the Squadron Operations Center, the Wing Operations Center and the personnel who will support the forward AOC should all receive a commensurate level of spin-up C^2 training and should practice their specific C^2 functions regularly.

The Air Force should actively explore the feasibility and practical utility of using DMT concepts and technologies to enhance the quality and availability of C^2 training and fulfill the goal of "training the way we intend to fight." Advanced DMT concepts exploit emerging weapon system connectivity, in combination with advanced simulation and modeling technology, to enable real-time collaborative operations among geographically separated systems. DMT technologies offer the potential to blend real, virtual, and constructive environments to produce a high-fidelity training experience tailored to the mission need and resource constraints. As DMT capabilities expand to mirror the operational environment, the distinction between training and operational domains will be systematically reduced or eliminated. Only the specific objectives

and outcomes of a particular application will dictate use of the weapon system, the simulator, and/or the constructive models as these become largely interchangeable tools.

As outlined in the 1999 SAB study on Operations Other Than Conventional War,[22] these higher levels of integration enable development of a Dynamic Mission Readiness Environment (DMRE) that can perform additional functions beyond that of distributed training. These technologies can be used to support a wide range of functionality, including experimentation, test and evaluation, tactics development and validation, operations, safety assessment, and risk management. DMT and DMRE offer the potential to greatly improve the vertical and horizontal integration of C^2 and AOC-level activities with those at the wing and squadron levels, providing the capability for daily immersion in the dynamic operational environment. This advanced capability should be pursued in an incremental, spiral fashion concurrent with other ongoing C^2 initiatives.

5.4.4 Personnel Practices

A comprehensive effort to strengthen C^2 professional career development should be instituted in the Air Force with principal responsibility assigned to AF/XO and AF/DP. Figure 5-5 identifies the major elements that must be in place to establish and maintain a viable force of professional C^2 warriors.

Figure 5-5. *Elements Enabling the Professional C^2 Warrior Force*

The first step is development of the professional warfighter career track. The AC2ISRC efforts in the C^2 warrior focus area for career path development are in line with this step, but we urge the expansion of current thinking to institutionalize the "aerospace warfighter track" illustrated in Figure 5-6 as a distinctive career path within the Air Force.

---

[22] SAB-TR-99-01, *Technology Options to Leverage Aerospace Power in Operations Other Than Conventional War, Vol. 1: Study Summary*, February 2000; information on DMT is on pp. 10, 52-55.

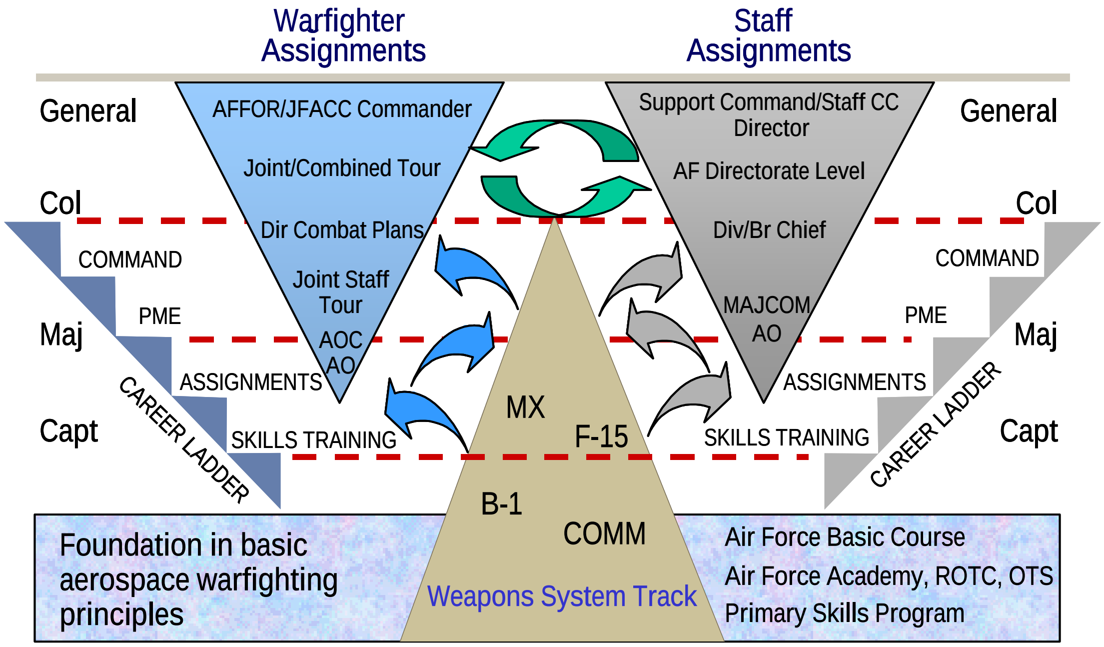


Figure 5-6. *The Professional Aerospace Warfighter Track*

In addition to notionally defining the professional C^2 warfighter career track, Figure 5-6 highlights the facts that the advancement opportunities would be clear to all and that visible equivalency with the staff track for advancement would be institutionalized. It is further recommended that all Air Force personnel receive some foundation in fundamental aerospace warfighting principles, including C^2, as part of their basic education at the entry level. A requirement should also be established for formal C^2 training or experience as a prerequisite for promotions above Lieutenant Colonel. Establishing fully functional AOCs and the expansion of training opportunities recommended in Sections 5.4.2 and 5.4.3 would greatly facilitate the realization of this career path alternative.

A second critical step is the expansion of personnel data management to establish an enterprise-wide qualification tracking system that supports education and training, maintains personnel and training records, and provides the personnel code designations at a level sufficient to rapidly identify the C^2 skill set of individuals. Again, the AC2ISRC has initiated an effort to at least clarify and expand the Software Engineering Institute codes. This initiative should be endorsed but extended further to enable complete and efficient access to the databases on personnel management, special skills, and training and to other relevant databases. A comparison of the existing personnel tracking scheme and the expanded skills management framework is presented in Figure 5-7.

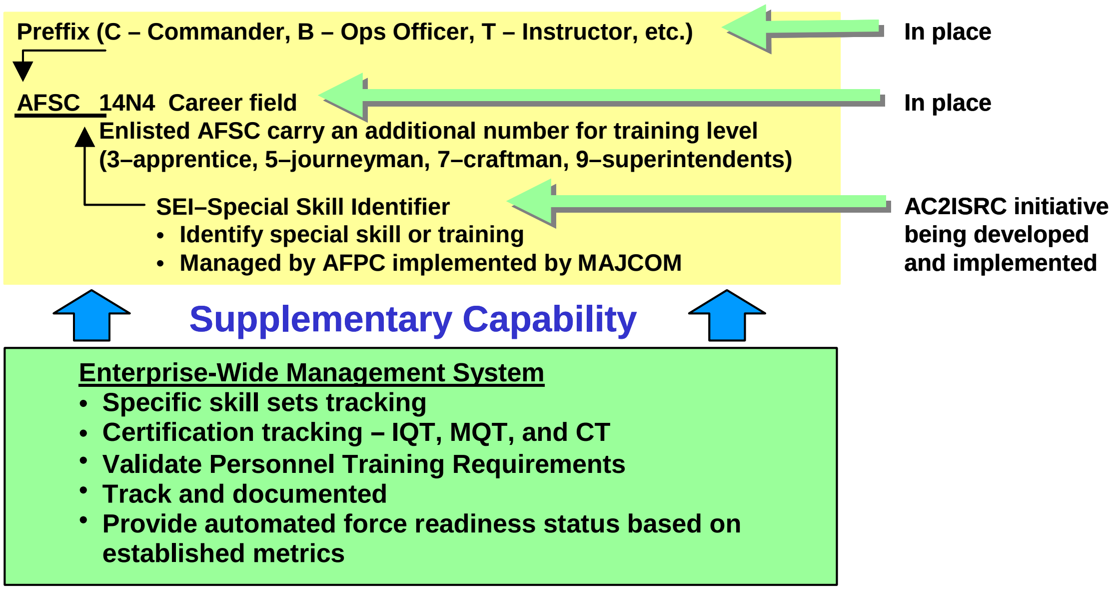


Figure 5-7. *Expanded Capability for Tracking of Personnel Skills and Experience*

For the above measures to be effective, they must be supported by an incentive structure that provides tangible evidence of the value and priority assigned to C^2 by the Air Force leadership. Promotion opportunities for C^2 specialists must reflect the importance of the jobs they perform and the level of competence with which they execute their jobs. Some possible actions to strengthen the perceived value of C^2 include

- Explore the Chief of Staff of the Air Force "contribution-based pay" initiatives such as professional warfighter pay for qualified colonels similar to medical pro-pay and the aviation continuation bonus (that is, implementation for all functional domains, including C^2)
- Provide promotional opportunities honoring the premise that "all warriors are created and treated equal" (that is, a parallel to joint assignment and promotion potential initiatives)
- Make career advancement and/or preferred assignments contingent on C^2 training, experience, and qualifications
- Re-orient the bonus system to reward qualified volunteers for hard-to-fill, remote, and/or hardship assignments
- Establish a course or program of weapons school caliber that results in a specialty designation for key aerospace command positions and enhanced promotion opportunities for graduates

In combination with the improved training opportunities and daily operations, these measures provide the foundation upon which a professional C^2 warrior force can be built and maintained. It is essential to note, however, that all of the elements identified in Figure 5-5 are inter-dependent and must be addressed in a balanced, coordinated fashion to realize the desired results.

5.4.5 C^2 System Design

Effective integration of operational experience and human engineering design principles must be accomplished early in the HSI development process, since they often impact architectural and/or software design decisions that are prohibitively expensive to change at later stages of

development. For this reason, a structured, systems engineering approach, comparable to that employed routinely in the development of the HSI for combat aircraft, should be applied in the acquisition and modernization of future C^2 systems.

Figure 5-8 shows an example of a process for improved human-system integration. The diagram shows a fundamentally mission-driven approach, with requirements, functions, operator tasks, and performance metrics all derived directly from (and traceable to) the mission. This process also heavily emphasizes user involvement at all stages of system development and testing, using rapid prototyping and part-task simulation tools to actively engage users in assessing alternatives and evaluating operational utility as the design evolves. The iterative nature of this approach is entirely compatible with spiral development and provides for effective transition from development to operations, sustainment and incremental upgrades.

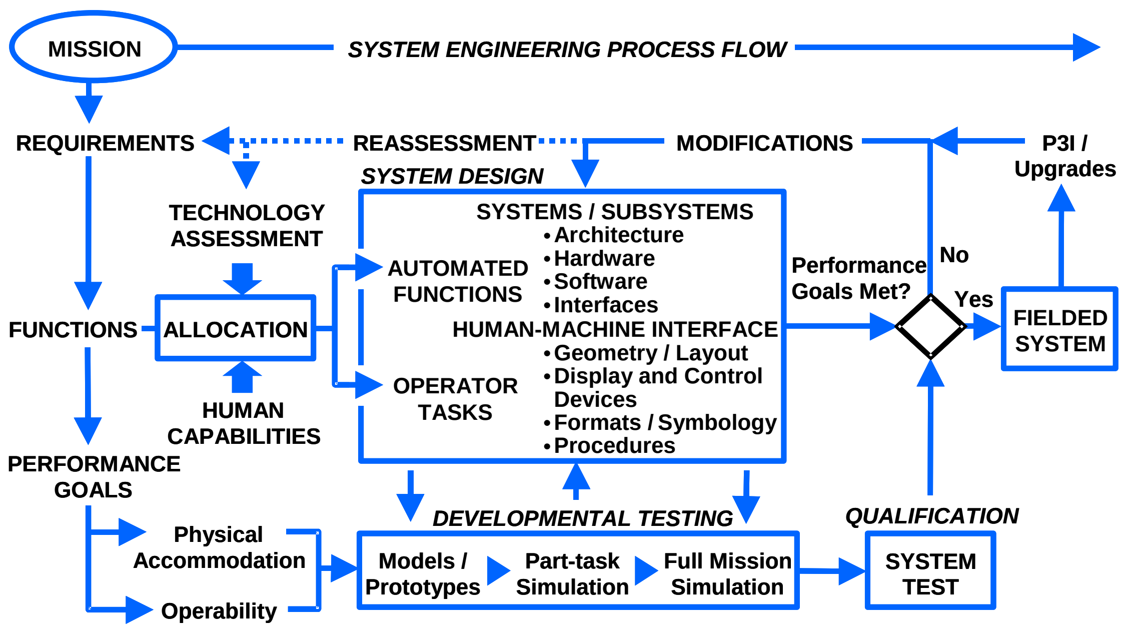


Figure 5-8. *Human–System Integration Development Process*

Several actions should be assigned by SAF/AQ for implementation by the Air Force Materiel Command and its product centers to institutionalize this type of systems approach to HSI integration in the acquisition process. These include

- Establish a structured process like that in Figure 5-8 to ensure effective HSI integration
- Establish usability goals as key performance parameters
- Include HSI effectiveness criteria in the source selection process
- Tailor and apply Military Standard 1472 and Military Handbook 46855 as appropriate
- Recommend establishment of HSI compliance criteria and processes for Defense Information Infrastructure Common Operating Environment certification
- Require training in HSI for program managers (similar to the U.S. Army MANPRINT program)

An important action for the ACC C^2 operational leadership is to define a reference mission and baseline CONOPS prior to the initial cycle in the spiral development process for new C^2 systems.

In addition, a multi-disciplinary HSI advisory group, including both HSI professionals and operators, should be established to oversee the implementation of the HSI process.

5.4.6 Human-System Interface Technologies

Selected examples of technologies with near-term potential for C^2 applications are described below. It is recommended that the AC2ISRC, in cooperation with AFRL and the C^2 Battlelab, investigate their utility and feasibility (along with others listed in Table 5-2) through prototyping and experimentation.

- **Automated speech recognition** (ASR) technology is sufficiently mature to provide an intuitive interface for an operator. ASR would allow the operator to bypass the menu structure by means of natural language commands. The payoffs would be faster creation of the ATO with fewer errors. Faster spinup of augmentees would also be facilitated.
- **3-D audio displays** can drastically increase the intelligibility and effectiveness of multi-channel speech communications by spatially separating the apparent locations of speech signals presented to the operator over headphones. This makes it much easier to monitor multiple simultaneous talkers for critical messages and to focus attention on the critical talker in the presence of other competing speech messages. 3D audio displays also make it easier to determine the origin of speech messages and can improve situational awareness by providing intuitive information about the locations of objects relative to the listener. 3D audio is a mature technology that has been demonstrated in numerous flight tests and can be inexpensively implemented in new communications systems.
- **Untethered technology** is being developed to allow battle commanders in Information Operations (IO) and C^2 operational environments mobile access to the information and people in their organization, even when they are not physically near their organization's computers and databases. These technologies include, wearable computers, handheld and palmtop computers, and personal digital assistants. This line of technology development will facilitate battle commander interactions with wall-size and PC-based information displays and operational information databases, as well as facilitate communications with other command staff as they move from place to place within the organization. They will also allow the use of a wide variety of computer peripherals, such as speech generation technology and laser-based visual display controllers, without the cumbersome "umbilical cords" typically required to use these capabilities. Many warfighter organizations have identified the need for untethered, mobile technologies to support operational battle staffs as a significant factor in improving human decision making in wartime environments in the future.
- **Simple decision support systems** that model the dynamics and uncertainty of the work environment using Bayesian inference techniques can be used to support contextual attention focusing and alerting of the warfighter. These systems would provide a "flag" (for example, an on-screen alert or an audible tone) when critical event thresholds are exceeded. Any alerting would be provided with the current work context taken into account to ensure that the alert is offered in the right format at the right time and that it does not increase the cognitive burden on the warfighter (see Appendix 5D for further detail).
- **Information visualization** technologies are available to provide commanders and their staffs with displays to aid their comprehension of large volumes of data. Visualization tools shift information processing from lexical to spatial realms to enable rapid discovery, understanding, and presentation of data. AOC visualizations can be used in mission preparation and planning and in mission monitoring and assessment to portray the combined (air, space, and information) tasking.

- **AOC recording capability** could provide the AOC with "performance instrumentation" that is similar to that used to characterize and improve the performance of test aircraft. There is an emerging capability to record screen captures of the displays in the AOC at regular intervals. Tools must be developed that help commanders and operators better understand the processes employed in the AOC—so as to rapidly interpret anomalies and adjust, compensate, or change the processes as decision cycles increase in speed, complexity, and frequency. Academic researchers have developed process capture and reuse tools that can record audio and video of AOC activities. This multimedia data can then be indexed by screen capture shots taken from the data management systems that the team uses in the AOC (for example, large-screen tactical display or individual workstations). This could produce an easily navigated and reusable record of AOC activity during operations and exercises. Such a system could be used for briefings, de-briefings, crew changeover, post-mission effectiveness assessment, requirements definition, training, experimentation, and development of decision support tools.

The field of cognitive systems engineering can also provide improvements to the methods and tools employed in developing C^2 decision support systems. Some of the more promising tools for C^2 applications include

- Cognitive Work Analysis—a systems approach to identifying the constraints in a domain and using these constraints to guide the design process
- Cognitive Task Analysis—a set of methods for describing the cognitive skills needed to perform a task
- Decision-Centered Design—the use of cognitive task analysis to specify the difficult decisions and to use these as a basis for designing HSIs and decision support systems

Appendix 5A
People and Organization Panel Charter

The panel served as the technical arm to advise the Concept and System Definition Panel on human-system integration matters relevant to the 2005 system implementation. The panel also made recommendations to the Acquisition Panel on process improvements to ensure that human-system requirements are adequately addressed in procurement of future systems and in near-term upgrades to existing systems. The scope of effort addressed human-system integration issues for

- Ground-forward
- Ground-reachback
- Airborne battle management C^2

The panel assessed the allocation of functions to humans and automation in present Air Force C^2 systems, and the process and criteria for making these decisions. The panel was also charged with identifying technologies and methods to optimize utilization of human and automated resources to maximize operating efficiency.

With regard to the HSI, the panel was asked to consider information flow in both directions (C^2 flow-down and feedback mechanisms). The study focused on presentation of relevant, critical, timely, accurate information to decision makers at all levels. This included dissemination and presentation of all mission-essential information and the establishment of necessary levels of situation awareness for commanders, analysts, planners, and aircrews. The panel was asked to recommend technological improvements in the areas of display media, control devices, automation, and decision-aiding to enable needed improvements in C^2 systems. The panel also assessed the readiness of key HSI technologies for near-term (2005) and long-term applications.

The panel addressed personnel-related issues that impact C^2 system effectiveness, including selection, placement, training, and certification of C^2 specialists. This effort focused on problems associated with meeting the demands of high-tempo expeditionary deployments and their impact on the skills, qualifications, readiness, and retention of personnel. The panel made recommendations regarding concepts and/or processes to help ensure that the right person can be immediately deployed and employed in response to time-critical threats. Current Air Force organizational practices for C^2 were reviewed to determine whether they are conducive to

- Rapidly getting qualified people (and equipment) to the crisis scene
- Ensuring that training and readiness are effective and “as we fight”
- Providing career ladders for the people—officers and enlisted
- Applying contractor support where appropriate
- Controlling personnel tempo

The panel was also asked to identify and address human-system issues that impact integration of C^2 systems for joint or coalition operations. These findings took into account lessons learned from recent Air Force deployments and combat operations.

(This Page Intentionally Left Blank)

Appendix 5B
People and Organization Panel Membership

Mr. Jeffery B. Erickson, Chair
Manager, Crew Systems
The Boeing Company

Col Lynn Carroll, USAF (Ret)
Private Consultant

Col Roger Carter, USAF (Ret)
Program Manager, Advanced Information Systems
Lockheed Martin Corporation

Dr. Emily Howard
Technical Fellow
The Boeing Company

Dr. Miriam E. John
Vice President, California Division
Sandia National Laboratories

Maj Guy Jones, USAF (Ret)
Senior Systems Analyst
SenCom Corporation

Dr. Gary Klein
Chief Scientist and Chairman of the Board
Klein Associates Inc.

Prof. M. Elisabeth Paté-Cornell
Department Chair, Management Science and Engineering
Stanford University

Col Bruce Queen, USAF (Ret)
Director, Advanced Program Development Airborne Ground Surveillance & Battle Management Systems
Northrop Grumman

Dr. John Reising
Technical Advisor, Crew System Integration Division
AFRL/HE

Lt Gen John B. Sams, Jr., USAF (Ret)
Director, C17 Field Services
The Boeing Company

Col Hugh Smith, USAF (Ret)
Manager, C^2 Operation
TRW, Systems and Information Technology Group

Advisor: Col Marc Lindsley

Executive Officer: Maj Juan R. Berrios, ACC/INXX
Technical Writer: Capt John M. Feland, USAFA/DFEM

(This Page Intentionally Left Blank)

Appendix 5C
Available Command and Control (C^2) Training Opportunities

Joint Forces Air Component Commander (JFACC) Course. The JFACC Course is the senior (joint–Service O-7 level) professional military education course offered by the Air Force to prepare potential JFACCs for theater-level leadership responsibilities. Particular emphasis is placed on air power employment in theater-level operations using Theater Battle Management Core System (TBMCS) and other related equipment that will be available to future JFACCs. The JFACC course is 4.5 working days long—3 days at Maxwell Air Force Base, Alabama, and 1.5 days at Hurlburt Field, Florida.

Joint Air Operations Senior Staff Course (JSSC). The JSSC is a senior professional military training program. The course uses presentations, discussions, and physical equipment to provide an overview of the planning, coordination, integration, employment, and implementation of air operations strategy in joint operations. The program is designed to prepare colonels (or O-6 equivalents) and/or specifically selected lieutenant colonels (or O-5 equivalents), selected by their respective Numbered Air Forces or equivalent organization, for senior leadership responsibilities in a Joint Aerospace Operations Center (JAOC). Presentations by a General Officer JFACC and three current directors from three JAOC locations lead off the program, followed by each Service's operating considerations in a JAOC. Course length is 4.5 days.

Command and Control Warrior Advanced Course (C^2WAC). The purpose of the C^2WAC is to prepare selected Air Force officers to perform duties that require advanced knowledge, skills, and ability in the C^2 processes supporting the Joint Force Air Component Commander or Commander, Air Force Forces, decision making at the operational level of war. In keeping with the mission of the C^2 Training and Innovation Group, the C^2WAC contributes to advancing the C^2 state of the art. Individuals entering this course should be field-grade officers, normally with a minimum of 1 year experience in an AOC, across the functions of A-1 through A-6, including space, information operations, and mobility.

Graduates of the C^2WAC should be qualified to assume supervisory positions (cell/division chief) within an AOC.

Joint Aerospace Command and Control Course (JAC^2C). JAC^2C focuses on C^2 of joint air operations in a theater battle at the operational level of war. This course covers basic doctrine, mission, and organization of the services; the Theater Air Ground System, command, control, and communications systems; intelligence support capabilities; tactical missions and major weapons systems used in joint operations; capabilities and limitations of C^2 warfare concepts and strategy; and computer tools used in current operations. The course includes lectures, seminars, hands-on computer activities, a C^2 exercise prior to the final exam, and end-of-course Initial Qualification Training certification by functional area.

Joint Aerospace Systems Administrator Course (JASAC). JASAC trains selected individuals in the fundamentals of UNIX, and Windows NT System Administration Terminal Control Protocol/Internet Protocol networking and communications protocols, relational database TBMCS administration. The course focuses on individuals assigned to system administration duties within the JAOC, Numbered Air Forces, composite wings, or related joint organizations or facilities. Course length is 40 days.

Joint Aerospace Computer Applications Course (JACAC). JACAC trains selected individuals in the fundamentals of TBMCS operations, focusing on training individuals required to use TBMCS in a JAOC, other joint organizations, or closely related facilities. Individuals attending the course will normally be assigned duties at a JAOC, Battlefield Coordination Element, Control and Reporting Center, or other component facility. Course length is 4 days.

Joint Combat Search and Rescue (JCSAR) Coordinator Course. JCSAR Coordinator Course provides individuals with needed information for functioning in a Joint Search and Rescue Center (JSRC) and to be aware of the dynamics involved in one. The course exposes students to the procedures and requirements for establishing and running a JSRC or a component-level Rescue Coordination Center. A cursory overview of the Personnel Recovery program will be provided. This and many other aspects will be used to recover personnel in distress in an Area of Operations. Course length is 4 days.

Appendix 5D
Risk-Based Decision Support Systems for Commanders
Elisabeth Paté-Cornell

Quantification of uncertainties, for example, probabilities of target destruction in combat assessment, is currently done informally based on experience, at least by some commanders. This process includes sequential updating of the probability of success, based on pilot reports and sensor data. It also involves a threshold of probability above which the commander is confident enough that a given target was destroyed to proceed with further operations. Automation of this individual thinking process, through small, *simple,* computerized systems, is feasible and would be helpful in managing the fog of war. Applications include combat assessment and choice of sensor(s) for a given task.

Based on Bayesian logic and probabilistic risk estimates, these combat decision support systems could automatically provide a "flag" when specified thresholds of probability are exceeded. These systems have to stand alone and be easy to use. They could be implemented, for instance, in small hand-held computers that could be docked into larger systems when useful statistics can be found elsewhere. Key input will include the probability of an event *before* reports and signals, the probabilities of errors (false positives and false negatives) in intelligence reports and sensor data, and the thresholds above which the probability of the event of interest is high enough that there is no need for additional information. Some of these data (for example, the performance of sensors) can be gathered and processed centrally. But for the most part, these decision support systems are to be fed and updated at the local Air Operations Center level, *based on on-site information*, for example, the prior probability of the event of interest given the local conditions. The confidence level ("flag") required before further action must be determined by the commander.

The results of these models must be transparent, comprehensible, and checkable against intuition to verify that all relevant factors that the human mind would instinctively (and often implicitly) account for are included in the computation. The benefits of these support systems could include faster results, fewer people involved in intelligence processing, enhanced accuracy, and provision of *knowledge* rather than *data*.

Probability figures cited by an experienced commander as an illustration of an informal way of doing this reasoning seem to be conservative in the probabilities rather than in the "flag" used for decision making. The combination of probabilities that appear conservative and of a threshold that seems low permits the commander to determine, in the end, the degree of risk to take. The problem is that conservatism in the probabilistic estimates makes it difficult to maintain consistency when combining information from different sources. It is more logical when computing a single risk figure (to be compared to a "flag") to use mean probabilities (for example, mean future frequencies), and to put the desired conservatism in the threshold that triggers the "flag" (that is, a higher threshold). This approach, without significantly modifying the reasoning, would allow consistent use of the best available information and accurate combination of probabilities while preserving the desired level of conservatism in the decision.

(This Page Intentionally Left Blank)

Chapter 6
Report of the Acquisition and Program Management Panel

6.1 Introduction

The Acquisition Panel examined the acquisition process to acquire and evolve command and control (C^2) systems to support the decision-makers in air operations. Our particular focus was on theater C^2 systems—such as the Theater Battle Management Core System (TBMCS)—acquisition and evolution. We took the following approach in developing our findings and recommendations:

1. We developed a list of desired attributes of an acquisition process for C^2 systems.
2. We described the current Air Force acquisition process for C^2 systems (and everything else) by doing a case study of the TBMCS acquisition as a normative example.
3. We searched for examples of other acquisition processes that might better satisfy the desired attributes for C^2 systems.
4. We formulated our findings and recommendations for modifying the current Air Force acquisition process for C^2 systems—especially for the Theater Aerospace C^2 System (TACCS)—the focus of this study.

We determined that an evolutionary **integration** process similar to the one used by the Defense Information Systems Agency (DISA) in evolving the Global Command and Control System (GCCS) is more appropriate than what we have used in the past for acquiring and evolving C^2 systems. This process also involves evolutionary **development**, but in a much more timely, diffuse, and distributed way than it has been done in the past in the Air Force. In addition to integration and development process changes, we agree with the other panels that major improvements are needed in institutional focus on C^2 in the Air Force (it should be a core competency), in advocacy for a coherent Air Force C^2 program (we need an Air Force Council Representative addressing C^2 and its supporting structures alone), in funding for the proper infrastructure to do integration of new capabilities into C^2 systems (a program element [PE] funded and advocated by the Air Force Materiel Command [AFMC]), and major restructuring and consolidation of program elements and Air Staff panels.

6.2 Approach and Visits

The first meeting of the summer study was conducted on 7 March at the U.S. Air Force Academy. This was a panel-chair kick-off meeting to review the Terms of Reference. On 8 March, the Acquisition Panel Chairman met with the General Manager of Lockheed Martin Colorado Springs, Mr. Pete Rogers, to discuss the TBMCS program and general acquisition approaches for such programs.

The next meeting was the Air Force C^2 kick-off meeting at Hurlburt Field, FL on 20-21 March. The panel was hosted by the Air Force C^2 Innovation and Training Group and received study guidance from the Air Force C^2 Study Chairman, Dr. Worch. The panel also received briefings from Maj Gen Perryman (Commander, the Aerospace Command and Control, Intelligence, Surveillance, and Reconnaissance Center [AC2ISRC]), Lt Gen Kenne (Commander, Electronic Systems Center [ESC]) and BGen Obering (Assistant Secretary of the Air Force, Information Dominance [SAF/AQI]).

The Acquisition Panel then visited ESC 3-5 April for an information-gathering meeting. Lt Gen Kenne hosted the panel and her staff provided briefings on Global Air Traffic Management System, TBMCS, Spiral Development, the Joint Surveillance Target Attack System (JointSTARS), Integrated Space Command and Control (ISC^2) program, Joint Expeditionary Force Experiment (JEFX), Joint Battlespace InfoSphere (JBI) and a number of other programs.

The entire Air Force C^2 study then convened at Langley Air Force Base (AFB) on 10-11 April and was hosted by AC2ISRC. Maj Gen Perryman and his staff provided various briefings on Combat Air Force (CAF) C^2 and visitors also took a tour of the Air Combat Command Network Operations Security Center.

The next information gathering meeting of the acquisition panel was on 18-20 April in Washington DC. Panel members met with Ms. Darleen Druyun (Assistant Secretary of the Air Force, Acquisition [SAF/AQ]), BGen Gary Salisbury (DISA/D-6) and Mr. John Gilligan, (DOE/Chief Information Officer [CIO]), who was previously the Program Executive Officer (PEO) of Battle Management, and under whose aegis the integration of the Contingency Theater Automated Planning System (CTAPS), the Wing Command and Control System (WCCS), and the Combat Intelligence System (CIS) into the current TBMCS program was initiated.

The entire Air Force Scientific Advisory Board then met at Nellis AFB, NV for the Spring Board Meeting on 24-27 April. The Air Force C^2 study received additional briefings from ESC. The panel also received briefings on RED FLAG and toured the RED FLAG facilities.

On 28 April, panel members traveled to Colorado Springs to visit Lockheed Martin concerning TBMCS specifically. The panel met with Mr. Steve McCulloch and Mr. Reese Delorey, the initial and current Lockheed Martin TBMCS program managers.

Maj Gen Nelson audited major portions of an Armed Forces Communications Electronics Association-sponsored GCCS course in Washington DC on 8-12 May to gain further insight into the current GCCS program.

Panel members traveled to Washington DC on 16-18 May. The panel met with the following individuals to get their opinions on the GCCS integration process as well as their specific recommendations on the acquisition process for TACCS:

- DISA/D-6, BGen Salisbury
- Space and Naval Warfare System Command (SPAWAR), Dr. Frank Perry
- SAF/AQI, BGen Obering
- Deputy Chief of Staff, Air and Space Operations (AF/SC), BGen Bell
- AF/XOC, Maj Gen Hess
- AF/XOJ, Maj Gen Baker
- AF/XOR, Mr. Disbrow
- AF/XPP, BGen McNabb

The Chairman participated in a Panel Chairs' meeting at Woburn, MA on 13-15 June.

The panel returned to Washington DC on 26-27 Jun to meet once again with DISA—Ms. Dawn Hartley; Ballistic Missile Defense Organization—Lt Gen Kadish; SPAWAR—Dr. Frank Perry; and the Advance Information Technology Service Joint Program Office (JPO)—Mr. Jim Moody.

All panel members participated in the report development phase at San Jose, CA 10-21 July.

The Chairman went to Wright-Patterson AFB on 7 August to collect information at AFMC Headquarters (HQ). He met with the AFMC commander, Gen Lyles, and Lt Gen Kenne and Lt Gen Raggio, commanders of ESC and Aeronautics Systems Center.

6.3 Desired Attributes of an Acquisition Process for C^2 Systems

The process defined in the Department of Defense Directive (DoDD) 5000.1[23] for the acquisition[24] of major systems is still, even in the current revision, slanted toward the big dollar hardware systems such as F-22—and that is probably as it should be. But there is a major difference between these big hardware systems and C^2 systems—the basic technology to support system implementation is evolving at a much higher rate for the latter. And, in addition, the ability to clearly define the requirements for the system in the latter case is much more difficult. It is really true that the operator will know whether or not he likes a capability of a largely software-based C^2 system after he has tried it, while he knows even before a prototype is built what the basic capability improvements in a new fighter should be. Because of these differences, the assumption that one acquisition and sustainment process should serve all systems is an erroneous one. The C^2 process should allow much more operator modification, either through improvements made by the operators themselves while operating real systems, or through integration of new capabilities demonstrated in laboratories or such activities as Advanced Concept Technology Demonstrations (ACTDs) and JEFX. Hence, we postulate a more appropriate acquisition approach for C^2 systems in general as one that has:

- The interest and attention of senior Air Force leadership
- A planning, programming, and budgeting process that fosters cohesion of the components (for example, for the TACCS: JointSTARS, air operations center [AOC], Theater Air Control System, etc.) and continuity of development for appropriate components[25]
- A development and evolution/integration process that:
  - Allows for the recognition of need for new capability during system operation
  - Allows for the rapid integration of already developed and tested hardware and software to satisfy emerging new capability requirements
  - Allows for the rapid development, testing, and integration of new capabilities when and where needed
- Fosters continuous communication among the participants in the acquisition—especially including the actual users (as opposed to only with surrogates for them)
- An organizational structure and appropriate resources to execute the PPBS and development/evolution processes

---

[23] DoDD 5000.1 still describes a process which may be summarized as: collect and clearly state the system's requirements, develop and test a system implementation that satisfies those requirements, do an independent operational test to insure that the operational requirements are met, field the system and sustain it. It is implied that if a significant increase in capability is required, another acquisition cycle is needed.

[24] Acquisition is defined as development and procurement. For C^2 systems as well as for major hardware systems, there is a subsequent phase called sustainment—that includes evolution of the system (for example, block changes for airplanes), but for C^2 systems, evolution is a much more significant activity than for major hardware systems.

[25] "continuity of development" means avoiding the "big bang approach" discussed in footnote 1 above—and instead instituting a continuous development and integration process—much like we define sustainment after a major system's initial development and fielding.

- Clear definition of authority and responsibility (for example, who owns the concept of operations [CONOPS], who speaks for the (joint) users in defining the requirements, who directs the contractors involved, who makes decisions on operational suitability...)
- Development and integration entities primarily motivated by the success of their efforts

6.4 The Current Air Force Acquisition Process for C^2 Systems

6.4.1 Acquisition Management

Based on the recommendations of the Packard Commission to improve the Department of Defense's (DoD's) organizational arrangements and acquisition management procedures, the Goldwater-Nichols Reorganization Act was made a public law in 1986. The recommendations centered on increasing efficiency and effectiveness, reducing costs, and decreasing acquisition cycle times.

The Air Force implemented the Act, similar to the other Services, by the creation of a Service Acquisition Executive (SAE), PEOs, and program managers (PMs) to make up the Acquisition Management System. The statute provided a new Under Secretary of Defense (Acquisition) to provide overall DoD policy for procurement, research, and development. Most noteworthy was the appointment of PEOs to be responsible for a reasonable and defined number of acquisition programs. The PEOs would be responsible directly to the SAE.

In the reorganization, the former Product Center and Air Logistics Center Commanders were made Designated Acquisition Commanders (DACs) and were to provide support to the PEOs and PMs. The DACs would be decision authorities for assigned programs. DoDD 5000.2-R requires assignment of program responsibilities to PEOs for all ACAT I, ACAT IA, sensitive classified programs, or any other program determined by the SAE to require dedicated executive management. DoDD 5000.2-R further states that to transition from a PEO to a commander of a systems or logistics command, a program shall have passed Initial Operating Capability (IOC), have achieved full-rate production, and be logistically supportable as planned. The purpose of these changes was to provide stability to an organizational structure and make arrangements to place highly qualified people in charge of programs with the appropriate authority and responsibility. Decentralized execution and reduced bureaucratic layering would be the result.

The Air Force complied with DoD's guidance and Congressional legislation by removing layered procurement decisions and unaccountable acquisition officials from the Air Force structure. Major programmatic decision authority was removed from AFMC. Although the PMs now have a higher level of accountability, these streamlining efforts developed a process of program execution that is complex, interactive, and not autonomous. The basic question is, "How have these acquisition reforms increased effectiveness and efficiency of the Acquisition Management System where actual program execution takes place?" This question is more difficult because there are no metrics to measure the performance of the reorganization.

From the PEO and PM perspective, there has been a mixed reaction with regard to the results of the reorganization. Results are highly dependent on the personalities and attitudes of the participants. There is consensus that the PM's decision-making authority has been enhanced. With regard to acquisition management of C^2 systems, the assignment of portfolios to two PEOs and one DAC contributes to fragmentation of the TACCS. Previously, some C^2 systems were also assigned to Air Logistics Center Commander's (DACs) portfolios. These programs make

up the overall TACCS, but are not assigned to a specific portfolio for management. This leads to inconsistency and instability of the overall TACCS program. Further, the assignments of the PEOs and PMs to these programs have been shorter than the reorganization had planned. The Air Force has not controlled the reassignments to milestone achievement such as IOC, full rate production, and logistically supported systems.

Another goal of the PEO reorganization was to force system integration across individual portfolios. Since the original portfolio assignment, the importance and visibility of the TACCS program has increased. This suggests a reassessment be made to include all those programs within TACCS to enhance mission area integration. There are currently insufficient resources within each program element that makes up the TACCS program for overall integration. Therefore, the PEO/DAC portfolios currently miss the opportunity for commonality, interoperability, and standardization across the C^2 mission area.

6.4.1.1 Recommendations

- Establish metrics to measure the effectiveness of the PEO management system
- Stabilize assignments of PEO/PMs to match milestone achievements
- Reassess portfolio assignment of programs to a single PEO/DAC to enhance commonality, interoperability, and standardization

6.4.2 The Current Air Force Acquisition Process for C^2 Systems: A Case Study of TBMCS (abbreviated—full text in Volume 2, Appendix 6C)

The TBMCS program is the current Air Force flagship program for automating and integrating the planning and execution of the theater air war. Its five core functions can be defined as:

- Intelligence collection and evaluation
- Planning
- Generating and distributing the Air Tasking Order (ATO)
- Unit level scheduling of missions
- Monitoring execution of the ATO

TBMCS is intended to link these intelligence, planning, and operations functions through the integration of several legacy systems (or their equivalent functional capabilities), the most important of which are CIS, CTAPS, and WCCS. In addition, TBMCS migrates these key theater air warfare applications to the Defense Information Infrastructure Common Operating Environment (DII COE) platform. The complexity of this integration and migration was underestimated in the mid-1990s when the program was initiated (as have been most, if not all, similar integrations). In the recent words of the then-PEO: “It’s the most difficult program I have ever encountered.”

TBMCS has experienced a troubled and controversial history since its formal launch in late 1995, when Loral (now Lockheed Martin Mission Systems [LMMS] of Colorado Springs) won a six-year competitive cost plus award fee contract valued around $180 million. The program has suffered from significant schedule slippage, some cost growth, and major performance short

falls.[26] The original contract envisioned the fielding of three progressively more capable software releases. Instead, as of June 2000, the program still had not been able to successfully complete and field Version 1.0. In addition, the current Version 1.01 represents a significant down-scoping in the capabilities originally envisioned for the first release. As a result, TBMCS is now widely considered to have been a seriously flawed program with regard to its development process, at least in the early phases. The program now, however, generally seems to be on track. A detailed plan for the fielding and future upgrading of the system has been developed.[27] Nonetheless, its many problems in its early phases make it worth examining carefully for "lessons learned" for future Air Force approaches to C^2 systems acquisition. The following is a list of lessons learned gleaned from extensive interviews with the key Air Force PEO, PMs, and LMMS senior managers, as well as from examination of numerous program office documents and briefings.[28]

Lack of sufficiently detailed CONOPS, system architecture, and operational requirements. TBMCS was launched with a strong visionary high-level CONOPS and system architecture. However, these lacked the detail necessary to provide appropriate guidance to the Air Force and contractor PMs for development of the system. No formal Operational Requirements Document was ever produced.[29] The problem was compounded by the lack of consensus among the user communities over CONOPS and operational requirements, and by continual change and evolution. The constant refrain of the contractor remained: "Will the real user please stand up?"

Lack of consistent, strong advocacy leadership in the highest levels of the Air Force, and at the System Program Office (SPO) and contractor levels. Initially TBMCS had a few strong advocates in the highest levels of the Air Force. At one key point during the development phase, an Air Force Major, far down in the SPO hierarchy, acted as the de facto PM for nearly a year. The program lacked clear lines of authority and strong leadership both on the government side and the contractor side.

Inappropriate application of current acquisition reform (AR) doctrines of transferring greater system definition responsibility to the contractor. Partly by default, and partly because of DoD AR doctrine, the contractor was granted significant control over the development of the system operational architecture, configuration, and even CONOPS. The contractor senior management lacked the operational knowledge, technical skills, and initiative to meet this challenge effectively without greater guidance from the Air Force. Clear guidance was not forthcoming.

Use of a "big bang" development approach instead of a spiral development style of approach, which delayed fielding, and resulted in operator pressure to divert resources to fixing legacy systems. The TBMCS contract called for the development and fielding of three major software releases over a six-year period. The user community lobbied hard for a much

[26] The original contract value to the prime contractor was $35 million (excluding fee, zero base fee), with options that were eventually exercised amounting to $109 million, resulting in a total of $144 million. Award fees and miscellaneous changes raised this to $179 million. A category labeled "evolutionary Requirements (TTDs)" added an additional $161 million, for a total contract value in mid 2000 of $327 million. Mr. Stephen Kent, ESC provided this information.
[27] TBMCS passed its Field Demonstration Test in June 2000. An MOT&E was accomplished in late July.
[28] An extensive and detailed case history of TBMCS is included in Appendix 6C of this volume.
[29] CTAPS and WCCS did have formal System Operational Requirements Documents.

quicker fielding of initial capabilities. This led to the decision to divert significant resources to fixing existing fielded systems (CTAPS, CIS, WCCS). This effort proved far more difficult than anticipated, leading to significant delays in the program, because the fielded legacy systems were seriously flawed. In theory, a spiral development approach could have led to a much earlier fielding of initial capabilities, thus reducing the pressures to divert resources to fixing legacy systems.

Insufficient "jointness" in the original program planning. Failure to include sufficient joint vision in initial program planning contributed to the unanticipated need to rehost CTAPS to Hewlett Packard and SUN servers for Navy shipboard operations. This was identified as a major unplanned diversion of resources. In general, Navy requirements and needs were not sufficiently recognized in the early phases of the program.

Underestimation by both the government and contractor of the technical difficulty of integrating legacy systems. Multiple contractors had developed the legacy software modules, usually in conjunction with a specific lab and a specific user command. Thus the pieces that would make up TBMCS had no uniformity in architecture, computer language, etc. Little formal documentation existed, resulting in difficulties in transferring the necessary legacy information to LMMS. This problem was exacerbated by third party "associate" contractors that had no formal contractual relationship with LMMS. Third, some particularly troublesome modules, such as Force Level Execution (FLEX), were developed by labs as tech demos, and were not appropriate for fielding. In the case of FLEX, neither the SPO nor LMMS had direct control over development. Finally, virtually all the legacy modules were more immature technically than originally anticipated.

Inadequate process for controlling and screening requirements/capabilities development and additions. The user community continued to develop new modules and capabilities that were folded into the program. No process existed to assess, prioritize, and filter these, leading to much added integration work. Little discipline was exercised over requirements growth and change, since no clear baseline configuration was ever established early in the program.

Lack of an appropriate strategy for testing and fielding the system. The program did not develop a consensus on a unified testing concept and approach, nor on test metrics for judging success. A lack of a unified and detailed CONOPS resulted in the lack of a standard use pattern by users. Different testers, with different use patterns, and using different test metrics, conducted the various operational and fielding tests, producing widely varying results. This was a major stumbling block to fielding.

6.5 Other Acquisition Approaches for C^2 Systems

In the time allotted for collecting data, the panel was not able to do an exhaustive study of Government and commercial approaches to acquiring C^2 or C^2-like systems; however, the following four examples are worthy of note for their acquisition process and structure:

- DISA acquisition of GCCS
- Navy development of Global Command and Control System–Maritime (GCCS–M),
- Air Force ISC^2 Program

- Department of Defense Intelligence Information System (DODIIS) managed by the Defense Intelligence Agency (DIA) and the Air Force.

6.5.1 GCCS

6.5.1.1 The GCCS

In the mid-1990s DISA instituted a process for evolving GCCS. It replaced the mainframe-based Worldwide Military Command and Control System with a more capable modern system. The process follows a similar process put in place by SPAWAR in the late-1980s when that command tried to come to grips with multiple versions of several stovepiped C^2 systems operating in the Fleet. GCCS is the cornerstone of the command, control, communications, computers, and intelligence (C^4I) for the warrior and addresses the mission need statement for GCCS, 8 June 1995. GCCS, as a warfighter-oriented system, provides improved information processing support in the areas of planning, mobility, and sustainment to combatant commanders, the Services, and Defense agencies. GCCS consists of all necessary hardware, software, procedures, standards, and interfaces for connectivity worldwide at all levels of command; and supports and integrates a wide assortment of mission critical, inter-Service, Service, and site-unique applications, databases and office automation tools. It provides an open system infrastructure that allows a diverse group of systems and commercial-off-the-shelf (COTS) software packages to operate at any GCCS location with a consistent look and feel. GCCS users can readily access web-enabled applications and databases. The functional groups within GCCS are situational awareness, force planning, and office automation and messaging. GCCS has been characterized as a non-near-real-time system, but recent application integrations have brought it closer to dealing with the near-real-time environment.

6.5.1.2 DISA and GCCS Evolution

DISA's process to evolve GCCS is closer to a sustainment than a development process. It recognizes the rapid evolution of software, computer hardware, and communications technologies and seeks to save time and money by integrating capabilities (applications) into the GCCS after those applications have been developed in prototype form and found operationally useful through ACTDs, exercises, etc. This approach reverses, in a sense, the classical acquisition approach, which does operational testing after the major and costly work of requirements collection, development, and integration have been accomplished. (There will often have been a prototype developed and tested before the classical acquisition process is even started). The process depends on the applications having been developed, frequently over a few-year period, to be compliant with a supporting structure, or platform—in this case the DII COE. While an application may have taken years to develop and operationally test, the process of integration and fielding typically is done within two to three months.

The Joint Information Engineering Organization (JIEO) manages the evolution of the GCCS and the evolution of the COE. The DISA D6 is normally the Commander of this organization. There is no grand design or master set of requirements against which the system is evolved, rather—there is a new requirement identification and prioritizing process accomplished annually. The commanders in chiefs (CINCs), Services, and Agencies identify and validate requirements for new capabilities to be integrated into GCCS. Applications addressing those requirements are typically validated operationally in exercises, ACTDs, and the like—and have been developed in compliance with the COE (typically at level 7). A series of functional working groups overseen

by the Joint Staff J3 (recall, the GCCS is the CINCs' C^2 system) ranks those requirements, as the JIEO has essentially a level-funded budget each year and hence integration of all requirements cannot be accommodated.

Using primarily a set of facilities in the DC area (a principal one being the Operational Support Facility), the JIEO and its contractors integrate the COE-compliant applications which have been approved into the GCCS and distribute new software to well over a hundred sites worldwide. This integration typically takes a few months for each application, even though the development and operational test of an application may have taken a few years. Applications are fielded continually, usually a few per month. The integration cycle is shown graphically in Appendix 6D of this volume, and a recent schedule for applications fielding is in Appendix 6E. A list of all applications and their descriptions is at Appendix 6F. To execute this GCCS integration process, the JIEO has a budget of approximately $60+ million annually (PE 0303150K), mostly operations and maintenance (O&M) (some procurement), and mostly for contractors and facilities. There are also approximately 200 government personnel (mostly Civil Service) funded in other lines. For DII COE maintenance and evolution, DISA D6 uses approximately $25 million annually, mostly for contractors and facilities, along with 40-50 government personnel (mostly Civil Service). Supporting the whole effort are a number of other facilities and organizations, such as the JPO (the Defense Advanced Research Projects Agency/DISA), which facilitates development and ACTD transition (approximately $25 million annually, including approximately 50 contractors, facilities, and about 20 government personnel), and the Joint Development and Evaluation Facility (a mini CINC HQ), assigned to DISA D8. There are other facilities and participants as well. Procurement and sustainment funding is the responsibility of the individual CINCs.

6.5.2 SPAWAR and GCCS–M Evolution

It is important to understand the Navy structure for defining requirements and developing and acquiring C^2 systems. C^2 requirements stem from fleet originated needs and are forwarded to the Chief of Naval Operations, specifically the Director of Space, Information Warfare, Command, and Control, N-6.[30] These requirements are refined and become part of a balanced budget process, meaning that C^2 items are balanced against all other needs, including ships, aircraft or personnel, at the Office of the Chief of Naval Operations level. The requirements and the necessary resources are then passed to one of the Navy System Commands or a PEO for development and acquisition. Figure 6-1 graphically captures the essence of this centralized process.

The SPAWAR philosophy that has been used in acquiring and evolving GCCS–M is essentially the same as DISA's process in evolving GCCS. This is not surprising given that RADM John Gauss, who now commands SPAWAR, and Dr. Frank Perry, his Technical Director, created the DISA D-6 structure during their tenure in DISA and had defined the SPAWAR process several years earlier. RADM Gauss was the SPAWAR Program Manager for what was then the Joint Operational Tactical System (JOTS) system.[31] As program manager, Gauss's job was to bring JOTS under configuration control. He additionally realized that the many other stovepiped C^2

[30] Although some other Navy organizations have some involvement in C^4, N-6 is clearly the central point of focus and spokesperson within the Navy for these matters.

[31] JOTS, variously the Joint Operational Tactical System or the Jerry O. Tuttle System, an early fleet inspired and deployed C^2 system which was well accepted but not under adequate configuration control.

systems, each with distinct software, operating systems, and databases were costly to maintain and needed to be brought into a common system or retired. The process chosen was the beginning of the process now used for both GCCS and GCCS–M. In its very essence, that process is to define a COE and specify standards and a process for implementing applications that will run on this COE. This process is described in Appendix 6G of this volume.

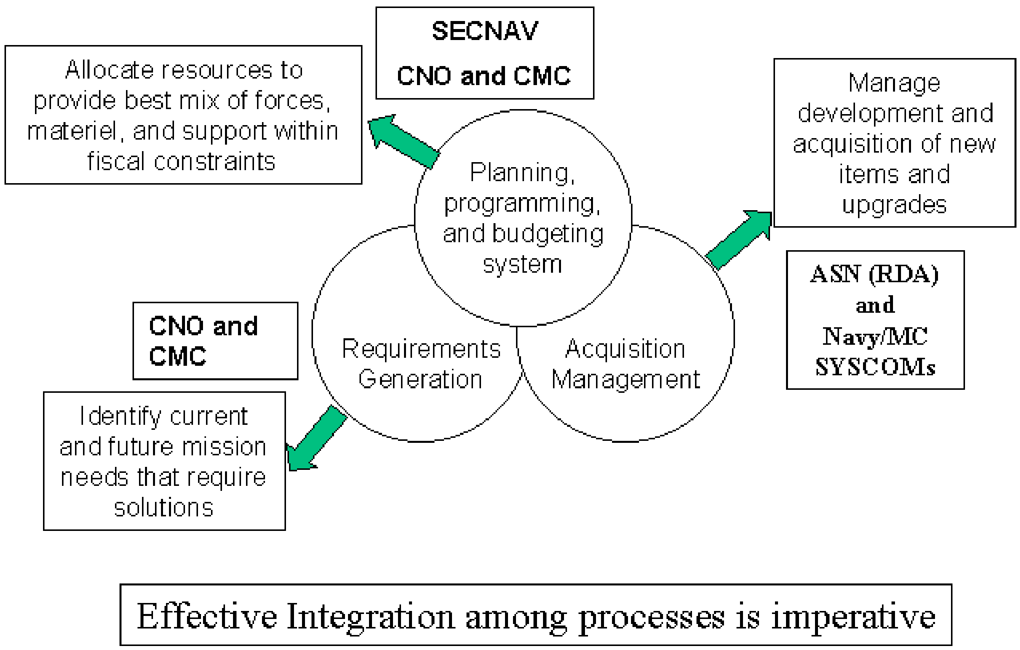


Figure 6-1. *Major Decision-Making Support Processes in the Department of the Navy*

Candidate applications for use on GCCS–M are frequently first demonstrated in naval exercises and then integrated into GCCS–M. SPAWAR has formed a strategic alliance with the Naval Warfare Development Command and has participated with them in Fleet Battle Experiments. Important thrusts like Time Critical Strike have found a pre-determined pathway through experimentation and prototyping to production deployment. Most of the development and integration work is done at two major SPAWAR field activities in Charleston and San Diego. The annual funding, including contractor support, is approximately $30 million RDT&E, $30 million O&M, and $120 million procurement. In addition, there are approximately 34 people in the HQ office for GCCS–M who are funded out of the HQ personnel resources. The GCCS–M program is at the ACAT II level. Fleet Commanders supplement the procurement funds by buying additional PC's and LAN backbones that SPAWAR installs. Under the Information Technology–21 (IT-21)[32] concept, SPAWAR is able to upgrade four Battle Groups or Amphibious Ready Groups each year with current versions of GCCS–M and concomitant hardware and supporting software. Grouping the fleet by Battle Groups, Amphibious Ready Groups, or Fleet Flagships yields 29 major afloat IT-21 installations including GCCS–M.[33]

[32] IT-21 is a Navy plan to up-date the information technology capability of each deploying Battle Group so that each ship in the Battle Group is raised to a common level of hardware and software for information technology.

[33] The 29 consist of 12 Carrier Battle Groups, 12 Amphibious Ready Groups and five flagships supporting numbered fleet commanders. One of the five flagships is in reality a command center in Bahrain supporting the Naval Component Commander in the Central Command.

Commonality between GCCS and GCCS–M is estimated at 95 percent. GCCS–M constitutes ½ - ¾ of each Battle Group's C^2 capability, not considering the combat direction capability of the ship.

6.5.3 Air Force Space Command (AFSPACECOM) and the ISC^2 Effort

The ISC^2 Program is being managed through a PEO, using ESC resources in the Strategic and Nuclear Deterrence C^2 SPO. Most of its few hundred people physically located in Colorado Springs, collocated with the Operating Command (AFSPACECOM); the remainder are at ESC. The SPO is charged with awarding a contract mid-2000 for a long-term (15 year) alliance with a single contractor. The contractor will assume Total System Performance Responsibility (TSPR) to evolve from the current North American Air Defense Command (NORAD) U.S. Space Command (USSPACECOM) Warfighting Support System (N/UWSS) to a target operational and system architecture that is being developed as part of the contractor downselect. The plan is that the effort will be level-funded, at the total level of the currently existing systems, which provide the as-is capability (approximately $100 million total annually in various appropriations, RDT&E, procurement, and O&M). DII COE compliance is required.

ISC^2 efforts. ISC^2 work will be concentrated in the following areas:

- Sustainment of new and existing ISC^2 systems
- Migration of existing ISC^2 systems to a common integrated architecture
- New C^2 capability development and fielding in a common integrated ISC^2architecture
- Achieving interoperability and collaboration among ISC^2operation centers
- Enabling and performing external integration of the ISC^2systems with Air Force, DoD, and other interfacing systems with emphasis on operation center/node interoperability
- Organizational level maintenance of ISC^2systems

ISC^2 contract. The ISC^2 contract will address USSPACECOM, NORAD and their component's ballistic missile/C^2 and related requirements (for example, N/UWSS). This includes both existing requirements, as well as those needs, like Information Operations, Shared Early Warning and Space Battle Management and Control emerging during the contract period of performance. The contract scope will also include system development, modification, integration, and support for other organizations with related missions (for example, U.S. Strategic Command's [USSTRATCOM's] Mobile Consolidated Command Center needs). The ISC^2 contract will evolve the as-is system to eliminate or mitigate the current system's shortcomings.[34]

A major objective is to create a long-term Government/Contractor partnership with the contractor realizing a sense of program ownership and allow the Government to reduce the size of the SPO. The contractor will manage and facilitate integration with systems outside the ISC^2 contract and establish a comprehensive and integrated training program for the lifecycle of all systems within the ISC^2 contract. They will provide SPO level integration, systems engineering, and test support across SPO programs. The minimum functions the ISC^2 contractor must cover include:

- Requirements impact analysis, coordination, and allocation

[34] N/UWSS Capstone Requirements Document, dated 21 February 1999.

- Integrated cross-SPO architecture activities
- Configuration management activities
- System-of-systems level enterprise information system
- Integrated scheduling
- Integration issue identification, tracking, and resolution
- Logistics planning for architecture evolution

The ISC^2 approach is different in some key ways from the DISA GCCS and SPAWAR GCCS-M activities. The main differences:

- The Air Force seeks to assign TSPR to the contractor on ISC^2, while the GCCS and GCCS–M efforts explicitly reserve it to the Government
- The Air Force seeks to reduce people resources required to manage a C^2 program by assigning most of the program management responsibilities to the contractor
- There is a target operational and system architecture specified at the outset of the Air Force/contractor alliance which requires an evolution plan to reach the goal from the as-is state. This feature is not in the GCCS nor GCCS–M programs
- ISC^2 is built on the DII COE as a main foundation—but not explicitly on GCCS. It must interoperate with GCCS, TBMCS, and USSTRATCOM

The other major difference is that the ISC^2 approach is yet to be evaluated, while the GCCS approach has been in operation for at least a few years. There are at least three similarities between the ISC^2 and GCCS/GCCS–M approach:

- Both assume a level of effort on a relatively long-term program to evolve the C^2 capability—this is a new approach for the Air Force acquisition structure
- Both evolve through integration of developed and operationally proven applications
- Both depend on a cooperative enterprise among user, acquirer, tester, and contractor

6.5.4 Department of Defense Intelligence Information System

The DODIIS architecture is managed by DIA and incorporates intelligence collection, processing, exploitation, and dissemination mission applications all existing in a common computing infrastructure. Individual applications are produced and maintained by the individual Services and various Combat Support Agencies (DIA, National Imagery and Mapping Agency [NIMA], and National Security Agency [NSA]). The DODIIS integration and testing process is very similar to the GCCS approach and has been in place for over five years. In addition to leading the technical development for the DODIIS infrastructure transition to DII COE, Deputy Chief of Staff, Air and Space Operations, Intelligence, Surveillance, and Reconnaissance (AF/XOI) manages the life-cycle development of several intelligence mission applications (via ESC/IC and Air Force Research Laboratory (AFRL), Information Directorate (AFRL/IF) procurements) and is also the Executive Agent for DODIIS integration and test. The Air Force coordinates all responsible test agency involvement, including the Joint Interoperability Test Center for interoperability testing, AFRL Joint Integration and Test Facility (JITF) for integration testing, DIA for security certification, and the appropriate agency or Service training certification. The JITF at AFRL/IF conducts integration testing to ensure each release of a DODIIS product meets the infrastructure requirements. Results of DODIIS testing/certification activities are reported to the DODIIS Management Board (DMB) via attachments to an

Acquisition Decision Memorandum. The DMB approves/disapproves deployment of individual products based on this input.

DODIIS implementation. All AF/XOI-managed DODIIS software programs utilize a spiral development process; examples include the Communications Support Processor (CSP), Information Support Server Environment (ISSE) Guard and PROJECT BROADSWORD. Each of these products have been successfully exported from the intelligence community to the Air Force C^2 community after incorporating C^2-specific requirements via "spirals." The GCCS-like DODIIS integration and testing process lends itself particularly well to spiral development due to parallel conduct of various test and certification activities and the less than 60-day integration certification timeline. The GCCS and DODIIS integration and test model focus on relaying specific infrastructure requirements to the developing program office early in the development process and assessing an individual product's evolving compliance towards these standards over its life cycle. Critical to the success of the GCCS and DODIIS models is the presence of a Management Board to decide deployment readiness. The GCCS and DODIIS models place more of the program management responsibility for scheduling, integration, and configuration management on the Government.

6.6 Oversight

Background. The AC2ISRC charter, dated 4 December 1998, ascribes certain Air Staff like functions to the AC2ISRC. Examples include the following mission statement excerpts:

"AC2ISRC serves as the lead organization to integrate and influence C^2 and intelligence, surveillance, and reconnaissance (ISR) for the Air Force. Primary tasks are to:

- Integrate air and space command and control, intelligence, surveillance, and reconnaissance operational and delegated systems architectures, roadmaps, requirements and standards in a continuing drive toward commonality, maximizing efficiency and reducing duplication of effort.
- Build aerospace C^2 and ISR modernization strategies, integrated mission area plans (MAPs), investment plans/divestment strategies, appropriate C^4I support plans, and associated programming documents that ensure Air Force C^2 and ISR will meet the challenges of Global Engagement and *Joint Vision 2010* and beyond.
- Ensure roadmaps, requirements, and the operational and delegated systems architectures are linked to the current Air Force Modernization Planning Process, the Air Force Strategic Plan, and Thrust Area Transformation Plans, or their future evolutions."

In addition, among the Center's responsibilities delineated in this same charter are:

- "**Architectures.** AC2ISRC will develop and maintain near term and long-term C^2 and ISR operational architectures for the Deputy Chief of Staff, Air and Space Operations (AF/XO), to include baselining Air Force fixed and deployable command centers. AC2ISRC will integrate major command (MAJCOM)/field operating agency (FOA) inputs in the design and management of the C^2 and ISR system-of-systems architecture in conjunction with the acquisition community. Operational architectures will be developed in accordance with the DoD command, control, communication, computer, intelligence, surveillance, and reconnaissance (C^4ISR) Architecture Framework document."
- "**Strategic planning.** AC2ISRC will lead the Air Force C^2 and ISR mission area planning processes, and produce the associated C^2 MAPs, ISR MAPs, an integrated C^2 and ISR roadmap, and other planning documents, to include C^2 and ISR investment plans/divestment strategies.

AC2ISRC will coordinate on all Air Force C^4I Support Plans and, when appropriate, lead the development of C^4I Support Plans. AC2ISRC will ensure C^4I Support Plans are complied with, especially in the area of interoperability and bandwidth and frequency spectrum utilization. AC2ISRC will ensure all Air Force C^2 and ISR acquisitions conform to interoperability standards required for joint certification. AC2ISRC will also establish liaison with DIA, the National Reconnaissance Office, NSA and NIMA to accomplish cooperative planning."

- "**Program Objective Memorandum (POM) responsibilities.** AC2ISRC will build and submit an integrated POM for aerospace C^2 and ISR forces with MAJCOM/FOA input and coordination. To accomplish this, AC2ISRC will:
  - Develop a strategic/long range vision, a C^2 and ISR roadmap and an investment plan/divestment strategy, and serve as the MAJCOM/FOAs' primary advocate for C^2 and ISR.
  - Build an integrated POM that reflects the roadmap and investment plan/divestment strategy, and assess MAJCOM/FOA compliance with the roadmap. All interested Air Force C^2 and ISR parties will be included in a deliberative, collaborative board structure for building the POM input. In the event of disagreement, all parties will attempt to reconcile differences between the MAJCOM POM and the integrated POM before submission to the Air Staff. In all cases, AC2ISRC will submit an integrated POM recommendation that meets HQ Air Force guidance. AC2ISRC will also include with this POM a C^2 and ISR update that will include the status of each program and a reconciliation between the C^2 and ISR roadmap and each C^2 and ISR program.
  - Review and provide recommended Air Force input to planning and programming guidance documents for the intelligence community. These include the Joint Intelligence Guidance for National Foreign Intelligence Program, the Joint Military Intelligence Program, and the Tactical Intelligence and Related Activities aggregation; the Program Manager's Guidance for the General Defense Intelligence Program; and any other pertinent documentation which may be issued by the Office of the Secretary of Defense (OSD) or national intelligence program managers. Through these reviews and comments, ensure that Air Force programs and capabilities continue to be interoperable with national capabilities and in compliance with national-level architectures and standards.
  - In conjunction with the appropriate Air Force component, assess the ability of aerospace C^2 and ISR POM submissions to meet the CINCs' identified needs and priorities. AC2ISRC will synchronize Air Force C^2 and ISR programs with Joint warfighting requirements to the maximum extent possible.
  - Maintain visibility of the execution and budget years.
  - When requested, attend meetings of the Air Force Planning Board of Directors, and serve as an advisor to the Air Force Board and Council."

Discussion. In executing its POM responsibility the Center functions almost exactly as the Air Staff Panel Structure in that MAJCOM inputs are received, reviewed, and integrated with other MAJCOM inputs; measured against a funding level; and then submitted as a balanced program, recommending funding levels for O&M and modernization. It is not, however, treated as such by the Air Staff, which receives the input and then refers it to the usual Panel/Board Structure for dissection. These panels have important responsibilities, but an integrated C^2 system is not among them.

The POM structure is the foundation on which the Integrated C^2 System is built. Recent events, most noticeably the 2002 POM submission, indicate that the current Air Force structure, as noted above, is not conducive to supporting or modernizing our C^2 structure. AC2ISRC POM input,

generally praised as a balanced, well thought out, integrated effort, was basically altered at Air Force level. Suggested offsets were taken, but not used to source other C^2 elements. The AC2ISRC budget was downsized by approximately 6 percent in an era where information management technology has been demonstrated to be a force multiplier in both military and commercial enterprises. While this paper is not to suggest that AC2ISRC should be immune from review, it does suggest that the AC2ISRC needs a senior champion on the Air Staff to assure C^2 receives due consideration in the Air Force priority schema.

A look at the Navy Staff is instructive here. The Navy C^2 organization is centered on the Chief of Naval Operations, N-6. This position is normally a three star flag officer, however, at this time, a two star officer, RADM Dick Mayo, fills it. The N-6 is responsible for setting C^2 requirements and providing the funding necessary to support the required research and development, procurement, and O&M funds to support communication, information warfare, and C^2 programs. The requirements for these programs are initiated by and provided to N-6 by the Fleet CINCs. N-6 makes the initial attempt to balance any disparities into an equitable program, which is then presented to N-8 for evaluation and balance with all other Navy program areas. After the budget for Navy C^2 is determined, the funds are provided to the commands which will be responsible for procuring the required systems or making the required modifications/modernization.

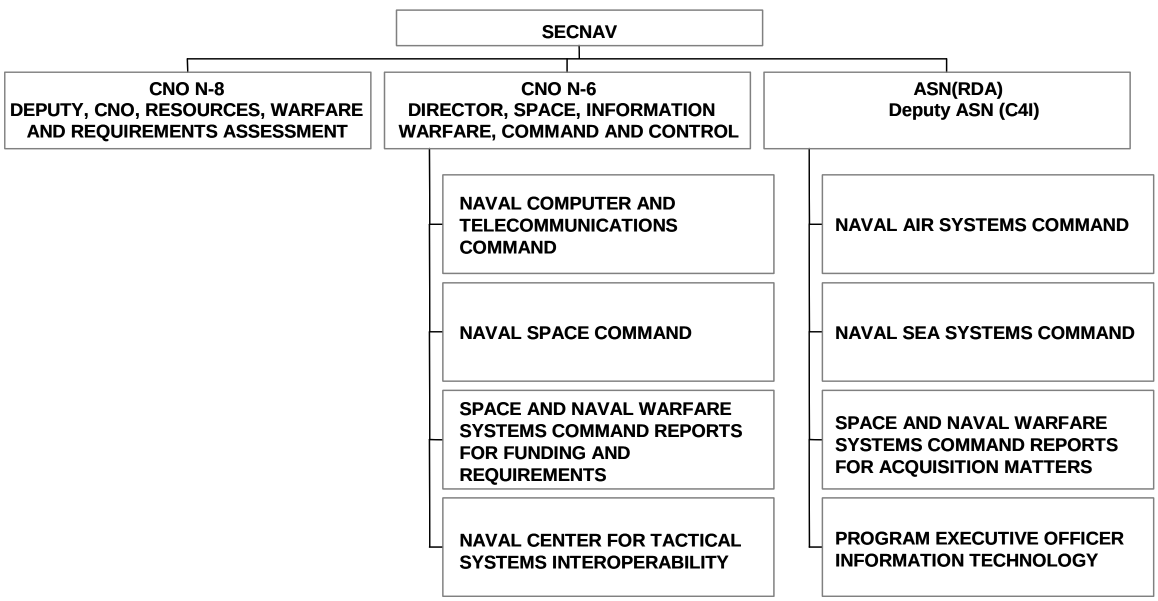


Figure 6-2. *Navy C^2 Organization*

As shown in Figure 6-2, the Navy C^2 system is more closely aligned with development/ acquisition responsibilities and Navy staff. Recent Navy studies have called for an even stronger and higher level organization to oversee C^2, suggesting the creation of a functional commander for operations information and space command. This officer would report to the Three Fleet Commanders, in the same manner that the current platform commanders report.

The Navy model described above, suggests the creation of a command, control, and communications "Czar" for the Air Force. This individual would be the focal point for C^2 on the Air Staff and assure that C^2 has the appropriate priority in the Air Force budget. A further and

necessary function of the command control and communications "Czar" would be to assure that the Command (CAF, SPACECOM, USSTRATCOM, Air Mobility Command) and functional (logistics, personnel, medical, finance) C^2 systems do not become (or continue to be) individually and collectively stovepiped but move toward appropriate levels of integration. These are not trivial issues and must be addressed at Air Staff level. Since solutions to C^2 issues have proved to be elusive to date, a presence on the Air Force Council seems mandatory.

We have considered several alternatives to source and place this position:

- Create a new three star position for C^2. This provides the positive attributes of unity of purpose, right level, show of resolve to attack the C^2 issue. It would require creation of an additional three star billet in the Air Force or elimination of a field three star position and movement to headquarters.
- Add C^2 czar duties to the Air Force CIO position. This shows high level resolve but the CIO is currently a SAF/AQ additional duty. The incumbent is not and would not be an operator or a member of the Air Staff Council.
- Add the task to AF/XO. Again, this would be an additional duty but would show resolve and could be staffed by an operator. It is not at the correct level, as it would undoubtedly be delegated below three star level.
- Use the current AF/SC 3-star billet to create a new position on the Air Staff (with Council membership) for C^3. Move appropriate 3-letters (for example, AF/XOI, AF/XOC) under this Deputy Chief of Staff (DCS). Leave appropriate AF/SC three-letters in the DCS. Staff with operators with C^2 experience. This provides close to unity of purpose, is at the correct level, shows resolve, allows an operationally oriented incumbent, and utilizes an existing billet already in HQ Air Force. It eliminates the emphasis on communications and networks which was deemed appropriate some time ago.

Findings. The C^2 system, to attain its potential as a force multiplier and provide flexible, deployable capability to CINCs and Air Component Commanders, requires a well-constructed modernization program that is sustained over time. To this end, a senior level advocate is needed at Air Force level to champion C^2 as a priority among the other Air Force requirements. The incumbent would use the AC2ISRC as a primary resource for constructing the C^2ISR Plan as delineated in the AC2ISRC charter.

Recommendation. A senior level (three star) staff position be created from the existing AF/SC position to oversee the important mission of modernizing and sustaining the Air Force C^2 System. Appropriate resources from the Air Staff should be reassigned. The AC2ISRC would be an important part of the incumbent's operation and the AC2ISRC should be assigned as a direct reporting unit (some elements of the AC2ISRC might best remain in Air Combat Command [ACC]).

6.7 Programming and Budgeting

AC2ISRC is charged with overseeing the entirety of the Air Force C^2ISR systems. This function currently encompasses a budget of approximately $9 billion per year and 117 separate PEs. Many of the PEs were created under a different, non-integrated management concept and require realignment so that they fit into a logical management structure. This process has started with the creation of a PE for the Tactical Air Force's AOC, but needs to be extended to the remaining PE structure.

When AC2ISRC was established, a number of PEs were assigned to its stewardship. Some of these were clearly part of the AC2ISRC overall mission and were therefore “core”. Others were not directly part of AC2ISRC but they had an interest. These were “non-core” and were under the Center’s cognizance but were not owned. In total the PEs were about 130 in number. Since that time the number has decreased to 117. The size of individual PEs varies widely from $500 million per year to $100,000 per year. Given that each PE drives an overhead structure, if only in considering funding levels, support at AC2ISRC and in the Pentagon, and justification to the Office of Management and Budget and the Congress, some savings in effort if not in people can be made by consolidation. In addition, consolidation in some logical sequence will provide the much-needed flexibility to quickly react with funding to solve issues or leverage new technology without reprogramming. The structure of the consolidation needs careful attention, as each of the PEs carries a constituency in terms of military, industrial, and congressional proponents.

Two methods of logically cataloging the C^2 PEs were considered: by node (as in AOC, Control and Reporting Center, Airborne Warning and Control System [AWACS], etc.) or by capability (as in ground target attack, air target attack, etc.).

Some pros and cons for each follow:

NODES

Pros	Cons
• Recognizable, physical entity	• Exists, therefore good enough
• Known capability and perceived deficiencies	• Already formed opinion as to limitations
• Easy to understand at all levels	• Easy target for detractors
• Flexible reprogramming	• Integration neglected
• Overarching integration possible	

CAPABILITY

Pros	Cons
• System of systems approach	• One system may fit in many capabilities
• Difficult to envision, many possible solutions to the same question	• Diffusion of funding across many PEs for single physical entity
• What we’re really trying to achieve	• May not be clear how much is enough
• Flexible reprogramming	

In order to properly integrate the C^2 system, each program element in the structure must contain funding and direction to provide the tools and system management to assure that the program element merges within the existing and future operational and system architecture.

Recommendations

- Reorganize the PE structure in a node construct.

- Relate PEs that provide operational capabilities through capstone program management directives (PMDs), or some similar structure, to assure that focus remains on fielding capabilities, and not just systems.

6.8 Requirements and their Control

6.8.1 Requirements Process

The formal Air Force requirements process in use for all systems is a formal, sequential process which emphasizes broad-based corporate buy-in regarding broad operational capabilities and recommended solutions to mission deficiencies. This process is lengthy, sequential and can take from well over a year to several years before a final document is prepared which initiates acquisition activity. While this process is appropriate for large, well-defined systems such as aircraft, it is not responsive to the rapidly changing environment of information technology (IT) acquisition, where several generations of change may be experienced in the time taken to articulate a single generation of requirements.

The concepts of evolutionary acquisition and spiral development (EA/SD) have evolved to enable the acquisition system to cope with the accelerated pace of IT development. Similarly, this accelerated pace demands a revised requirements process that avoids lock-step sequential articulations of required operational capabilities and recommended solutions.

A requirements process responsive to EA/SD has fundamental characteristics:

- Iterative through the system lifecycle
- Intended to be used within EA blocks
- Focused on rapid delivery
- Performance traded for cost and schedule control
- COTS solutions used where feasible
- Flexible to requirements reflected in business and technical strategies
- Continuous user and tester involvement
- Flexible architecture
- Conducive to experimentation throughout the spiral process
- Based on new decision points such as stop, continue, change, field, and support

This process can only work if there is an overarching set of priorities based on operational concepts and operational architectures enabling coherent action by a diverse group of participants. These operational architectures or operational concepts have not been available to the acquisition community in the past. In fact, the TBMCS program did not even have a draft operational concept until ACC/CC created a Tiger Team to develop such a document in the Spring of 2000—*over four years after the (then) $180 million effort was put on contract, and a year after the first operational tests*. The using and acquisition communities apparently felt that a union of the three legacy systems' CONOPs was sufficient for a description of what should be expected from the integrated capabilities. (One has to ask why bother integrating the capabilities if that was the case?) There is still no operational architecture for the TBMCS, and to its credit, the acquisition community has taken on the task of developing such a document in the absence of activity in the user sector. One would suppose that it would normally be the job of the AC2ISRC to get such a job done.

It is clear that some level of description of the operational architecture desired is required before development or integration of capabilities into a C^2 system should be accomplished. But DISA and the Joint Staff J3 do not seem to think that necessary for GCCS, as it seems they do not have such a roadmap. It remains to be seen how effective that "seat of the pants" approach to evolution will be. They appear to determine, on an annual basis, what already developed (DII COE compliant) capabilities should be integrated into the GCCS. Approval of these annual capability increments then constitutes the Milestone Review by the Milestone Decision Authority (MDA) (see DoDD 5000.1). Such an annual process of requirements determination is much preferable to the ponderous process we have used on such as TBMCS—where we have tried to determine all the required operational performance at the outset, and then embarked on a development program to build a system to implement those requirements—while the user community is meanwhile modifying its ways of operating, and developing its own hardware and software to accommodate those operations. The resulting turmoil of requirements changes causes havoc in classical development programs such as TBMCS was. Frequent integration of relatively small capability improvements , under the aegis of an evolving operational architecture, appears a much better approach.

Recommendations

- To realize the Air Force vision of integrated C^2, needs must be driven by the C^2 concept of operations mapped into desired operational capabilities
- Desired capabilities (referred to as "desirements") need to be developed through direct interactions between "operators" and "acquirers"
  - The desirements must define the capabilities but cannot define how the capability is obtained
- The 5000 series of DoD Directives need to be revised to reflect the priorities and principles described above. In essence, we recommend mining the ACTDs, Lab efforts, JEFX, Industrial Developments, etc., for applications which have already been developed and shown to be operationally useful—prioritize them—and integrate them into the C^2 system under a level of effort funding concept.
- Do not use the classical, sequential approach: collect system requirements, develop, operationally test—this will guarantee the fielding of an obsolete system

6.8.2 Combat Support Information

Recent contingency operations such as Desert Storm, Bosnia, and Kosovo have proven the necessity to provide the Theater Commander with timely, accurate and trusted information. The Expeditionary Aerospace Force (EAF) concept relies on integrated systems to provide an enterprise view of combat support information. The core competency to support the EAF is Agile Combat Support (ACS). The program to implement the ACS concept is the Global Combat Support System-Air Force (GCSS-AF). GCSS-AF is also needed for its contribution to rapid mobility and information superiority, two other Air Force core competencies.

The current process for providing combat support information is too complex, fragmented and slow to effectively and efficiently meet warfighter needs. Current data has to be manually verified, wasting valuable time, and jeopardizing missions and lives. GCSS-AF must provide commanders real-time visibility of relevant blue order of battle information for in-garrison and deployed forces for operational missions at any location on the globe. The information assists the commander to control resources, plan, train, equip, deploy, employ, sustain, and reconstitute

forces across the full spectrum of military operations. The data included in the system vital to the success of the mission are shown in Figure 6-3.

During Kosovo, our current systems, primarily functional stovepipes, did not provide a way to access, integrate, or present this information. The support world turned to brute force (phone calls, e-mails, and faxes) in an attempt to assemble and verify this critical information. Our leadership lost confidence in the information provided. Weapons employment decisions were impacted.

In the summer of 1999, the Air Force CIO established a Tiger Team to pull together the requirements and strategy for achieving a strong and successful GCSS-AF. The report of the GCSS-AF Requirements Integration Tiger Team was published on 31 August 1999, and is included as Appendix 6H of this volume. The acquisition panel strongly supports the Tiger Team's recommendations.

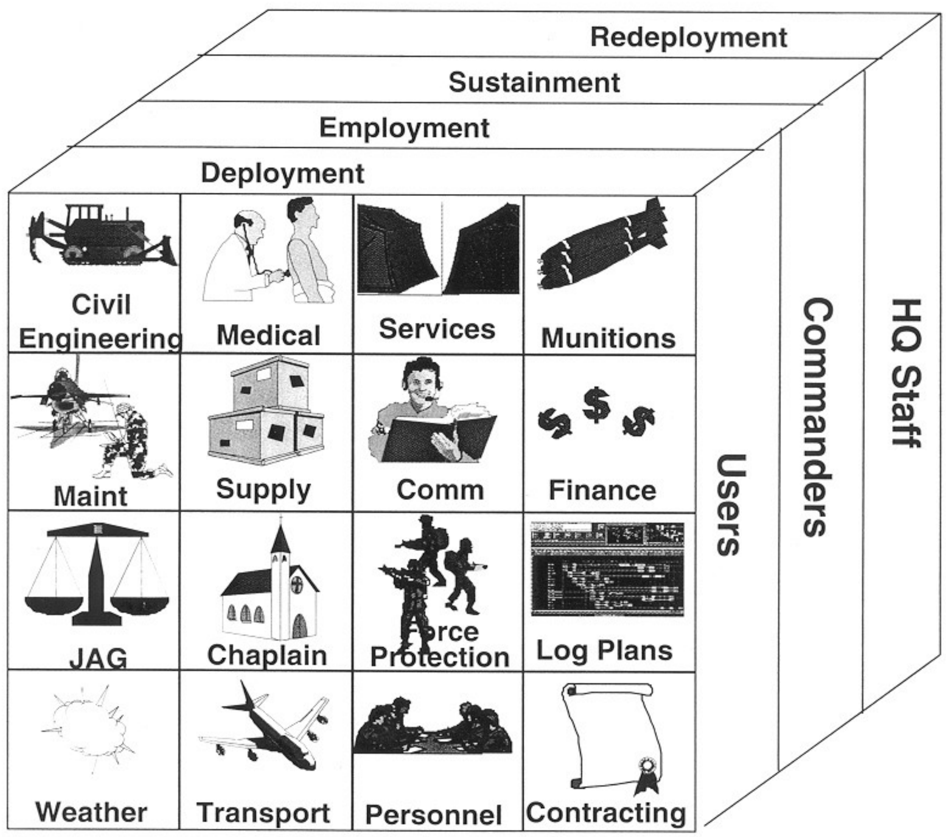


Figure 6-3. *GCSS-AF Information Cube*

6.9 Development and Integration Standards

In order to meet the Air Force evolutionary acquisition objectives of deploying new or upgraded integrated, and interoperable C^2 capability in a rapid acquisition timeframe (18 months or less); making use of the latest commercial IT, there are several processes and conditions that need to be employed. We believe these consist of:

- Well defined PEs encompassing desired warfighting functionality
- Stability in PE funding for development, fielding, and sustainment as a function of well defined priorities
- Disciplined requirements generation and control process (CONOPS, operational architecture, etc.) involving all stakeholders
- Defined technical architecture (information technology standards)
- Educated and disciplined use of the spiral development process
- Well defined objective system architecture and migration path
- Integration of test and evaluation (T&E) throughout C^2 development lifecycle

Many development programs fail or have limited success because one or more of these conditions are absent. Each is necessary in some form for successful evolutionary acquisition objectives. This section will focus on the items 5 and 6, as the other items are covered in subsequent sections of this report. For the purposes of this section, "development" is defined to include life cycle evolution of software-intensive systems and/or such related practices as legacy system replacement and integration of COTS or government-off-the-shelf components into an existing baseline system.

6.9.1 Evolutionary Acquisition and Spiral Development

The concepts of the EA/SD process have been studied, experimented, and implemented in academia, government, and industry to various degrees. The spiral development is a process initially described by Dr. Barry Boehm in the late 1980s.[35] In the 1990s it became more widely adopted throughout the software engineering community in various forms. Its basic notion of iteration has been generally accepted as preferable to a rigorous sequence of events ("waterfall") or large-scale rollout ("big bang") of a system. As defined by Boehm, spiral development is "a risk-driven process model generator…used to guide multi-stakeholder concurrent engineering of software-intensive systems." It is characterized by "a cyclic approach for incrementally growing a system's definition and implementation while decreasing its degree of risk." It must include "a set of anchor point milestones for ensuring stakeholder commitment to feasible and mutually satisfactory system solutions." Commercial IT companies practice EA/SD in some form as evidenced by the well know practices of alpha and beta release of products and regular formal version release of COTS products with increasing capability. However each company has probably developed its own unique versions of the process and the details are not that visible to the DoD community. Thus, the model and processes of determining objectives, alternatives, risk analysis, artifact development, stakeholder involvement, and decision-making are not visible. Although opinions vary on the acquisition system attributes where EA/SD works well, most feel there are significant benefits to be gained in its use in the Air Force C^2 domain. The Air Force leadership is convinced to the point that EA/SD is now directed for use on all C^2 acquisitions unless the user and MDA agree not to use it (Air Force Instruction [AFI] 63-123).

---

[35] Dr. Barry Boehm, "A Spiral Model of Software Development and Enhancement," *Computer*, May 1988, pp. 61-72.

State of C^2 Evolutionary Acquisition and Spiral Development in the Air Force. The Air Force has made an initial start at beginning a formal transition to EA/SD for acquisition of C^2 systems. Research, results, and guideline documents have been produced:

- Reducing Air Force Acquisition Response Times: Developing a Fast and Responsive Development System, 1 March 2000 (SAF/AQ)
- Air Force Evolutionary Acquisition Guide Draft, March 2000 (SAF/AQ)
- AFI 63-123 Evolutionary Acquisition for C^2 Systems, 1 April 2000 (SAF/AQII)
- Spiral Development Handbook Release 0.1, 1 June 1999 (ESC)

Some of the shortfalls in these documents are the lack of discussion of the spiral development "invariants, variants, and anchor point milestones" as defined by Dr. Boehm. Another shortfall is the lack of discussion of the importance of an "architecture first" approach. This doesn't mean that the operational, technical, and system architectures need to be totally defined first, but enough of it has to be developed up front to ensure that the first increment is sufficiently robust to allow subsequent scaling for additional later increments. Other subjects that are missing include explicit process guidance and tools for converging on next level objectives, constraints, and alternatives. These documents will need to be supplemented and revised based on implementation of recommendations in this report and other research results.

There are several on-going Air Force C^2 development projects that are explicitly using SD. The Global Theater Weather Analysis and Prediction System has completed several successful spirals and four incremental deliveries that are operational. This project is both developed by the contractor and deployed operationally at the user facility (AFWA) and this perhaps enhanced integrated product team (IPT) effectiveness toward user objectives. At one point a mini spiral was done in 6 weeks which resulted in an integrated capability to operationally track and predict hurricane paths. The Operational Weather Squadron Production System has also completed several spirals and is being deployed at the weather squadrons. The Attack Options Decision Aid is using SD and has successfully taken part in two JEFX experiments as a component in the time-critical target process. Although successful, the team has had some struggle with requirements management (growth) and development test and evaluation (DT&E) definition tradeoffs as a result of the team learning the spiral development process along the way. The JEFX experiments use the spiral process for integrating the experiment C^2 configuration infrastructure and initiatives, however very little capability has been transitioned to operational use at this point. The Space Weather Analysis and Forecast System is also underway as a spiral development and is about to begin DT&E of the first thread. This program has had to resolve an issue of the SPO wanting design documentation much like a waterfall development instead of waiting for as built design documentation. The Integrated Broadcast System was also started under EA/SD but was terminated just prior to completion and deployment of the first increment. The failure was in large part due to the lack of or ineffectiveness of the stakeholder IPT members in controlling requirements growth and identifying, analyzing, and focusing spiral efforts on the risks.

Perhaps the largest and most successful Air Force development program using spiral development (referred to as the Ada Process Model before the term "spiral development" was popular) was Command Center Processing and Display System–Replacement (CCPDS-R) for

Cheyenne Mountain Upgrade. The CCPDS-R project is discussed and well documented[36]. Its Ada Process Model was the predecessor of the Rational Unified Process and University of Southern California (USC) MBASE approach, which have been used on a number of successful spiral projects[37]. In addition, the CCPDS-R project used a number of working groups (display and user interface, algorithm, interface control, security, and test) throughout the life of the program with membership from all stakeholders. Decisions from the working groups were factored into subsequent design and software builds based on user inputs and risk assessment. The spiral process, including an "architecture first" approach, resulted in successful incremental delivery of three subsystems (missile warning, forward user processing and display, and USSTRATCOM unique) on a fixed price incentive contract. Incremental delivery of operational capability within a subsystem was not acceptable because of the nature of the operational ITW/AA mission, which could not be performed with a partial capability.

There are a few other projects that have had SD characteristics even though they didn't start out explicitly with the SD objective. These are Eagle Vision and Air Force Operations Resource Management System. Both have produced incremental capabilities using a spiral like process.

The Air Force also has some success employing evolutionary acquisition/spiral development methodologies in other communities. AF/XOI manages several DODIIS intelligence mission applications and acts as the executive agent for test and integration for approximately 35 systems developed under the General Defense Intelligence Program. The DODIIS development, integration, and test model implements the DoDD 5000 and 4630 Acquisition and Interoperability Directive, and is consistent with the Clinger-Cohen Act of 1996. Detailed DODIIS standards and instructions provide managers, developers and users with guidance relative to programming and budgeting, DII compliance, configuration management, test and evaluation, training, IT security, and software deployment. This process has been largely adopted by DISA for GCCS integration and testing. DODIIS compliance testing occurs in the Air Force-managed JITF. Spiral development programs successfully developed, fielded, and maintained by the Air Force for DODIIS include the CSP, the ISSE Guard and most recently, PROJECT BROADSWORD.

At this point in time, the overall Air Force EA/SD experience and results are limited and mixed. It is likely that a major reason for mixed results is that training and experience at the project IPT level has been very limited and thus the individual teams are feeling their way along.

The 2000 USC/Software Engineering Institute Symposium on Spiral Development. A number of organizations are successfully applying the spiral development model (SDM) and finding it valuable in addressing such challenges as rapid development, COTS software integration, new technologies, and product-line management. Other organizations have experienced difficulties with spiral development due to over-relaxed controls, underestimated risks, existing sequential development policies, inflexible financing mechanisms, ingrained cultures, and confusion about what spiral development is and how to apply it. To attack these problems, a workshop was held February 9-11, 2000 at the University of Southern California under the sponsorship of its Center for Software Engineering (CSE) and the Software Engineering Institute (SEI) of Carnegie Mellon University.

---

[36] W.E. Royce, *Software Project Management: A Unified Framework*, Addison Wesley, 1998.
[37] Boehm et al., "Using the Win-Win Spiral Model: A Case Study," *IEEE Computer*, July 1998, pp.33-44.

The Workshop objectives:

- Clarify the nature of spiral development
- Create a common understanding of the current state of the practice ("as-is")
- Share experiences in applying it in various situations
- Identify its critical success factors
- Create a vision of best practice ("to be")
- Identify and address institutional barriers/inhibitors to successful spiral usage such as policy, financial, or cultural constraints

The results of the workshop are documented in "The 2000 USC-SEI Workshop on Spiral Development" March 2000, report number CMU/SEI 00-SR-06. The report can be accessed on the web at http://www.sei.cmu.edu/activities/cbs/spiral2000. The workshop participants and briefings were from academia, government, and commercial and DoD contractors. None of the workshop participants represented DoD organizations that actually used software developed with the spiral approach. This suggests that the user community has had little experience with products delivered under EA/SD, or is not yet aware of the large opportunity it affords them to influence near term delivered capabilities. A brief summary of key issues and recommendations from the workshop follows.

Dr. Boehm opened the workshop with a presentation on the following key concepts referred to as invariants:

- **Concurrent determination of all key artifacts.** Concurrent determination of all key artifacts means that the concept of operations, requirements, design, and code are all progressively defined as the system evolves through the spirals. This is essential to avoid premature commitment to system requirements, design, use of COTS, and cost/schedule/performance. The relative amount of each artifact developed in a specific spiral increment varies based on risk.
- **Recurring stakeholder review.** Recurring stakeholder review of objectives, constraints, alternative, and risks between spiral increments is an essential element. This avoids wasting effort in elaborating alternatives that will be unsatisfactory to the user.
- **Level of activity in each cycle driven by risk.** Level of activity in each cycle in each area is driven by risk. This is one of the most key differences between spiral development and incremental development. By focusing on risk areas and then targeting those areas for further development the overall level of risk in the system is driven lower and lower.
- **Degree of detail in all key artifacts driven by risk.** For the same reason, the degree of detail in each key artifact is also driven by risk
- **Management of stakeholder commitments via anchor points.** Using anchor points to management of stakeholder commitments is to avoid analysis paralysis, unrealistic expectations, requirements creep, architectural drift, unsustainable architectures, and traumatic cutovers.
- **Emphasis on system activities and artifacts versus software artifacts.** An emphasis on system activities and artifacts versus software artifacts is to avoid premature suboptimization of hardware, software and development considerations. The relative amount of hardware versus software development, of overall capability, and of degree of productization in each spiral increment should vary, as always, based on risk.

The full briefing can be accessed on the web at http://www.sei.cmu.edu/activities/cbs/spiral2000.

The first day and a half of the workshop were devoted to presentations by executives and practitioners representing government, commercial users, solution providers, and contractors. In retrospect, these presentations evoked these themes and comparisons:

- The term *spiral development* is not well defined or understood. For some it means any development approach with recurrent planning activities, while others add constraints such as "risk-based" and "anchor points."
- Spiral development can be sharply defined with *invariants* and *variants*; that is, those aspects that are essential in every spiral project and those other aspects which can differ between projects.
- *Spiral development* and *evolutionary acquisition* are different, but related. An evolutionary process qualifies technology before embarking on spiral development.
- Spiral development differs between government organizations and commercial organizations.
- Some spiral time cycles are still fairly long—two or three years—while others are much shorter—two to three months. Typically, longer cycles are found in government.
- Some of the critical success factors for spiral development:
  - Risk must be managed
  - The culture must be trusting
  - Stakeholders must be involved
  - The technology must be ready
  - Requirements must be flexible

The second half of the workshop was devoted to small work group sessions, each addressing a different topic. These groups were particularly charged with recommending concrete actions for progress. They made forty-nine recommendations which fall into seven categories:

- Define SDM: Refine and promulgate the definition of the spiral development model.
- Promote SDM: Spread awareness of the spiral model among developers, managers, and executives.
- Educate about SDM: Provide appropriate courses through universities and professional training organizations.
- Adapt to SDM: Revise policies, processes, and practices to encourage spiral development where appropriate. These recommendations were addressed primarily to DoD, but will reward use as a checklist for any large organization.
- Improve SDM: Explore the spiral development model and human behavior to determine what improvements are possible and how they should be formulated.
- Enhance teamwork: Improve teaming techniques, especially as they apply to spiral development.
- Study SDM: Conduct research to validate the spiral development model, evaluate its potential for return on investment, and determine the mutual impacts between it and people.

For each recommendation, the workgroup proposed an action agent, the person or group most likely to be able to take the necessary actions. In general, the *Define SDM*, *Improve SDM*, and *Study SDM* actions are expected to be done by universities and research centers, especially Center for Software Engineering and SEI; all parties must act on *Educate about SDM* and *Promote SDM*; and OSD should *Adapt to SDM* with respect to DoD policies, processes, and practices.

Findings

- The practice of EA/SD in the Air Force (and DoD) is ad hoc and not well defined
- There is no Air Force funding for implementing EA/SD as a core competency
- The existing AFI 63-123 on EA/SD does not provide adequate guidance to stakeholders. There is no description of the spiral development invariants, variants, and anchor point milestones. There is no explicit description of process guidance and tools available for guiding spiral processes and converging on next level objectives, constraints, and alternatives.
- There is no Air Force training program for stakeholders in the effective practice of EA/SD
- Academia is very interested in working with the Air Force, DoD, and industry in advancing the state of EA/SD.

Recommendations

- Continue to invest in EA/SD as a core competency
- Partner with USC and SEI in continued EA/SD development. Enlist USC, SEI, and commercial industry support in the review, improvement, and refinement of AFI 63-123 and SD handbooks.
- The Air Force (and DoD) needs to treat EA/SD as a key engineering/management capability for (software intensive) C^2 systems. Task SEI to develop a Capability Maturity Model (CMM) for EA/SD. The CMM would apply to all the EA/SD stakeholders, not just industry.
- Task SEI and ESC to develop a training course in the implementation of EA/SD
- Provide EA/SD team-building sessions for all new projects/program managers to get projects started on an efficient and effective collaborative pathway

6.9.2 System Architecture

Although system architecture development is just one of the key activities of spiral development, it is important enough to highlight in this section. The C^4ISR Architecture Framework 2.0 defines the system architecture view as a description, including graphics, of systems and interconnections providing for warfighting functions. For a domain, the systems architecture view shows how multiple systems link and interoperate, and may describe the internal construction and operations of particular systems within the architecture. For the individual system, the system architecture view includes the physical connection, location, and identification of key nodes (including materiel-item nodes), circuits, networks, warfighting platforms, etc., and it specifies system and component performance parameters (for example, mean time between failure, maintainability, availability). The system architecture view associates physical resources and their performance attributes to the operational view and its requirements following standards defined in the technical architecture.

As important as the operational and technical architectures are, it is often the system architecture that creates problems with C^2 acquisitions. A major part of the system architecture is that of automated information system(s) and the corresponding software architecture. These areas of the system architecture are often understood by a small group of computer science experts and are not well integrated with the rest of the system acquisition. It is also these areas of system architecture that have the most impact on the resulting "-ilities" of the system. This is where the system attributes of flexibility, scalability, reliability, availability, and security are built in and thus, have high leverage for system success or failure.

The spiral development process addresses these risks via the anchor point milestones of Life Cycle Objectives, Life Cycle Architecture (LCA), and other project unique milestones. The process evolves the system architecture, through architectural specifications, prototypes, COTS elements, and system architecture instantiations in order to evaluate the architecture attributes and manage the risks. For evolving theater C^2 systems, this may mean a periodic spiral of updating the objective system architecture and the migration plan from the current architecture to the new objective architecture.

6.9.3 Demonstration Based Development

The term "demonstration-based development" refers to a set of spirals and decision points within an EA increment but after the LCA anchor milestone used to periodically evaluate and validate elements of the operational, technical and system architectures and user interface attributes. Each demonstration needs to be conducted to exercise an intermediate software build with planned threads and scenarios to evaluate a subset of evolving system functions, performance, the "-ilities", and user interface. Continuous user involvement throughout the software life cycle is critical to user acceptance of the next fielded version. This typically includes user participation in IPTs during the functional requirements analysis, design (particularly for Human Systems Interface), training development, and test planning activities. Even more valuable is the user feedback from participation in the evolving increment demonstrations. Additional valuable benefits from the demonstration spirals are the forced attention to achieving a robust product and creating the basis for test agreements before DT&E and operational test and evaluation (OT&E).

6.10 A Process to Allow Rapid Integration

6.10.1 Introduction

One of the major differences between command and control systems evolution and that of weapons systems using more established technologies is the pace of technological change. New generations of digital hardware, software, and telecommunications technologies are frequently available in months as opposed to decades. This rapid evolution requires a command and control system evolution process that accommodates such change. The process defined in our current basic acquisition publications (for example, DoDD 5000.1) and requirements directives will not suffice. As noted above the intelligence and DISA communities have established a process which at least appears to do a better job of accommodating rapid evolution. They rely on an evolving set of standards for integration (the DII COE in the case of DISA) that allow newly developed capabilities (which may have taken years to bring to fruition) to be integrated in months into the evolving baseline C^2 or intelligence analysis systems. The classical development approach documented in such as 5000.1 assumes that such developments are treated as prototypes—and another whole development cycle (consuming again years) is used to integrate the new capability into the baseline system. While the DII COE standard may not be the best one, such a process appears to be the best available for integration of new capabilities into systems such as TBMCS.

It is the Air Force's desire to evolve toward web-enabled systems, and minimize the necessity to depend on cumbersome client-server architectures such as was the norm when TBMCS was started in the early 90s. This evolution is apparently what DISA is planning for the DII COE. It would seem worthwhile for Air Force to use DII COE as a near-term platform standard to allow

rapid integration of capabilities into evolving C^2 systems, and to steer the evolution of this standard toward one supporting the JBI. Support in the Air Force for the COE has been half-hearted at best, and it has frequently been treated as a needless and costly encumbrance. We need to adopt an approach for the integration of capabilities into joint systems which serve the CINCs which allows for integration of appropriate technology as soon as it makes sense to introduce it. The "big bang" development and integration approach will not allow that to happen.

6.10.2 Evolutionary Integration—The C^2 Testbed

An essential element to the development and integration of new C^2 capabilities is a testbed that can serve a combined and integrated team of operators, developers, integrators, trainers, supporters, and testers to provide a collaborative environment for the evolution of command and control. We heard many pleas for location at the Rome AFRL/IF Site and at Hanscom AFB, but we see the need to be close to the operators. We believe such a testbed should be established at Langley AFB, under the control of a management board including AC2ISRC, ESC, AFRL and Air Force Operational Test and Evaluation Center (AFOTEC) (plus Air Education and Training Command training and AFMC logistics personnel), with primary lead by AC2ISRC. While the main facility might be at Langley AFB, important satellite development, integration, and simulation work can and should take place at other locations (Hanscom AFB, AFRL/IF, operational AOCs, etc.)

Above all, the testbed should be populated with a joint team, a partnership, operating in a harmonious relationship between the activities concerned to the common goal of transitioning command and control development initiatives and operational concepts to the field. No person is in a liaison role: All are IT-operations professionals of high caliber with long-term assignments. Figure 6-4 describes the key responsibilities.

The testbed should be equipped with that equipment representative of fielded equipment, as well as that equipment that is necessary to perform the specific functions of the assigned responsibilities.

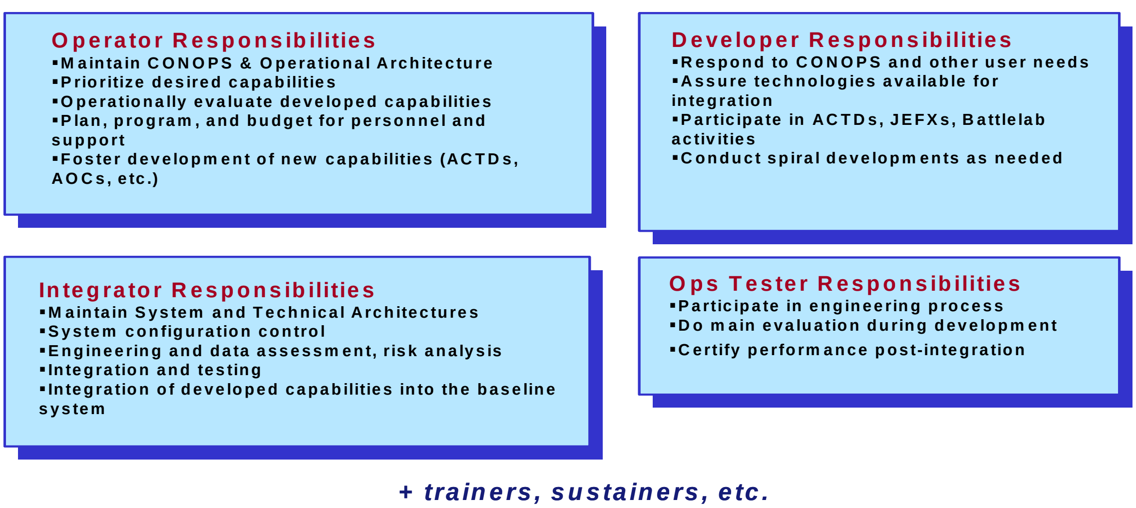


Figure 6-4. *Testbed Team Responsibilities*

The testbed would provide the basis for experimentation with operational and technical concepts, as well as the final tests of developments and the integration of capability into the operational systems in the field.

Figure 6-5 depicts the cyclical process. Operators develop operational concepts and architectures and identify new technology developments needed. Developers develop prototypes, demonstrations, and ACTDs as well as identifying new operational concepts made possible by technology advancements. Integrators develop system and technical architectures and integrate the new capabilities into the testbed, and later, into the operational system. Testers conduct capability testing (on a less formal basis than performance testing), and trainers develop training concepts. Much is done in parallel at the testbed, but the result is a cyclical refresh of the operational capability in the field. Major physical and functional components of the command and control testbed may be physically separated from the main facility.

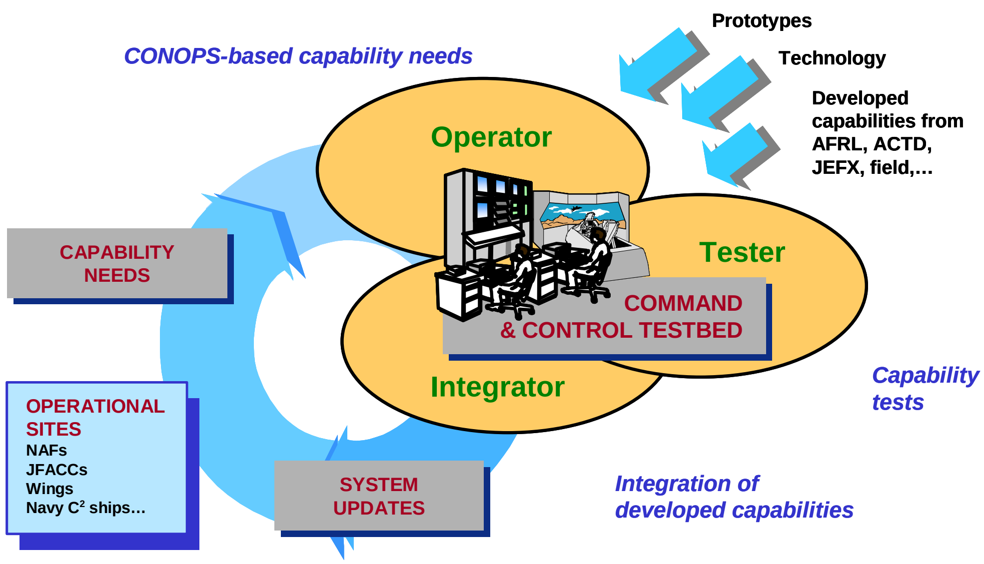


Figure 6-5. *Evolutionary Integration*

It is the Air Force's desire to evolve toward web-enabled systems, and minimize the necessity to depend on cumbersome client-server architectures such as was the norm when TBMCS was started in the early 90s. This evolution is apparently what DISA is planning for the DII COE. It would seem worthwhile for Air Force to use DII COE as a near-term platform standard to allow rapid integration of capabilities into evolving C^2 systems, and to steer the evolution of this standard toward one supporting the JBI. Support in the Air Force for the COE has been half-hearted at best, and it has frequently been treated as a needless and costly encumbrance. We need to adopt an approach for the integration of capabilities into joint systems which serve the CINCs which allows for integration of appropriate technology as soon as it makes sense to introduce it. The "big bang" development and integration approach will not allow that to happen.

6.11 Testing

T&E of C^2 systems is an evolving Air Force area of discipline. Beginning in 1995, the Air Force recognized that T&E of C^2, at the developmental test level was seriously flawed. A series of initiatives, stimulated by HQ AF/TE, resulted in establishment of a formal, structured, process-oriented T&E team at ESC. A staff element (ESC/TE) is responsible for ensuring that each ESC acquisition program develops and implements an adequate test program, incorporating appropriate contractor, development and operational testing.

6.11.1 Development Test and Evaluation

Development Test (DT), which may include contractor testing, is an integral part of the development process, and is primarily conducted in the early phases of a program. It is intended to evaluate design approaches, validate analytical models, quantify contract technical performance and manufacturing quality, measure progress in system engineering design and development, minimize design risks, predict integrated system operational performance, and identify system problems to allow for early and timely resolution or correction. OT&E (described below) cannot compensate for inadequate DT, since the DT phase is crucial to the technical system characterization that must precede OT&E.

6.11.2 Operational Test and Evaluation

OT&E, specifically initial OT&E, is the testing and evaluation conducted on production or production representative articles to decide whether to field a system or to characterize that system's effectiveness and suitability. In the case of C^2 OT&E, this characterization may be the most important function, since a spirally developed system seldom has a Milestone III-type episodic decision point. It is also important to note that OT&E is concerned with the use of the system in its intended environment and may evaluate system interfaces and performance even if those parameters were not included in the original specifications and design.

6.11.3 Complicating Factors

The classic DT and operational test (OT) structures described above were developed in the years before the instantiation of the significant acquisition reform activities of the 1990s. Initiatives such as COTS, Cost as an Independent Variable, Component Based Design and TSPR, while meritorious in many respects, all exert downward pressure on program costs with a concomitant pressure to reduce SPO-controlled DT. To the extent that DT is not comprehensive, OT must attempt to fill the gap or risk sending an incompletely characterized system to the user. In essence, the system must demonstrate stabilized performance in a stressing environment before productive dedicated OT can begin.

6.11.4 CONOPS and Operational Architectures

With C^2 systems in particular, the T&E concept is heavily dependent upon the intended framework for employment. The operational tester cannot adequately characterize a C^2 system and its performance unless the user and developer have produced a CONOPS and operational architecture which specify the system's intended use, the projected interfaces, and the planned operational benefits of the system. The CONOPS and operational architecture should therefore be required elements in the SPO's certification of readiness for IOT&E.

6.11.5 GCCS and T&E

The GCCS was examined as an exemplar for C^2 acquisition. While GCCS has numerous commendable program attributes, replication of that management scheme should avoid the following problems. First, there is no written operational architecture for GCCS. As noted above, such an architecture is crucial to effective operational evaluation and characterization of the deployed system. Second, it is not clear how the developing agency, DISA, conducts formal OT&E of deployed systems. This means that there is no stressing evaluation of either the complete system or its component parts in advance of actual operations. Extensive DT, interoperability, and security testing is accomplished but these essential activities do not compensate for the lack of installed, full-up system operational tests. Similarly, DODIIS rigorously tests at the component, interoperability, and security levels but also includes AFOTEC as the OT agent on many systems of Air Force interest. The DODIIS process is detailed in Appendix 6J of this volume.

6.11.6 Evolutionary Acquisition and Spiral Development

The Air Force has clearly specified most procedures for EA and SD in AFI 63-123. Left unspecified, however, are requirements for operational architectures and CONOPS. As discussed above, these elements are crucial to characterization of the system's effectiveness and suitability. Also unspecified is the specific form of OT&E. Unless the Operational Test Agency (OTA) is expected to be continuously involved for the life of an EA system, the architecture or CONOPS must indicate when and where capability improvements are expected. The OTA can then plan episodic events and subsequent realistic assessments of delivered operational effectiveness and suitability.

6.11.7 Findings and Recommendations

- An adequate CONOPS and operational architecture must be specified as part the Certification of Readiness for OT&E
- The current ESC/TE reinvigoration of T&E should be supported and those ESC programs without formal TE-approved test plans should be required to obtain such approval at an early date
- PEOs and DACs should ensure that acquisition reform initiatives do not result in less-than-adequate DT
- T&E procedures specifically tailored to support EA/SD should be developed and published by HQ U.S. Air Force

6.12 Infrastructure for Development and Integration

A major discussion and requirement regarding actual implementation of our recommendations has been left until this section. Any major enterprise normally capitalizes a set of facilities and operates a set of functions that allow it to pursue its business. In the case of information technology-oriented organizations, these are the testing and integration facilities, and the IT-unique evaluation, estimation, planning, architecting, and simulation capabilities necessary to the successful prosecution and integration of systems in this rapidly changing environment. In the early days of acquisition of aircraft, the military invested, and still does, in major simulation and evaluation capabilities—in the Air Force principally at Wright-Patterson, Eglin, and Edwards AFBs. In addition, with the inception of major new technologies in recent years, very significant

new investments were made in signature, electronic warfare, and other lethal and non-lethal evaluation capabilities—often Government owned and operated.

For some reason "the system" in the Air Force has not perceived the need for similar investment in the rapidly evolving and high leverage field of information technology. Our C^2 systems are therefore developed on a piecemeal, contractor-oriented basis, leading to the very stovepipes we are trying so assiduously to avoid. Facilities such as the Modeling, Analysis, and Simulation Center (MASC) and C^2 Unified Battlespace Environment (CUBE) at ESC have literally been bought with savings on the base electric and heating bills when winters were unexpectedly mild. Hardly the way to run a business! Indeed, the operating Commands have in all cases established capabilities which are much superior to anything that the C^2 development community has—and it has been done mostly with O&M money.

If we want to continue the stovepiping of Air Force C^2, then that is the way to go about it—to let the operating commands "do their own thing". We have done a top-level estimate of the kind of annual budget that should be provided to an organization such as ESC to allow it to operate in a fashion similar to the DISA's JIEO (see 6.5.1 above). A separate program element and budget, starting at approximately $66 million and leveling at $60 million annually should be instituted, advocated and defended by the Commander, AFMC, to allow ESC to build and maintain a proper infrastructure to accomplish its job. This would allow establishment of the following capabilities to support Air Force C^2 evolution:

1. Enterprise and Domain Architectures: Development/Sustainment

Realizing an integrated C^2 system with a common infrastructure depends upon an overall scoping and definition of capabilities that minimize duplication and maximize mutual utility among the capabilities. This is a key role of "architecture." Specifically, AFI 33-124, *Enterprise Information Technology Architectures*, recognizes three levels of architecture: enterprise, domain and program. The DoD C^4ISR Architecture Framework specifies the format for the products expressing military architectures. Responsibility for these architecture products resides with the MAJCOMs and acquisition agencies (per AFI 33-124). ESC and AC2ISRC, as the principal centers responsible for C^2, must prepare and coordinate the pertinent architecture products for the integrated C^2 system and its infrastructure.

2. Integration and Interoperability (I&I): Assurance and Certification Testing Development

It is necessary to have a state-of-the-art facility (CUBE) to support the development, integration, test, certification, and sustainment of integrated and interoperable C^2 weapon systems for the Air Force and DoD. The CUBE is augmented with a state-of-the-art MASC facility to support the development, integration, test, certification, and sustainment of integrated and interoperable C^2 weapon systems. These capabilities provide the basis for implementing Simulation Based Acquisition as an integral part of building in integration and interoperability to the IC^2 from the beginning of a new program or modification of an existing system. In addition these capabilities provides the Air Force Linkage to the Joint Distributed Engineering Plant for integration of Air Force C^2 systems with Navy and Army C^2 elements and supports formal interoperability certification and testing activities for Air Force C^2 systems.

3. Collaborative Tools in Support of Infrastructure Definition/Development

Infrastructure definition and development cannot be a stovepipe activity. It requires considerable interaction among all Air Force developers, testers, sustainers, and the user. Also, given the vast scope and amount of information needed it must have automated support. The state of collaborative tools is such that we can take advantage of them to assist in this activity.

In order to coordinate activities across warfighters, developers, testers, and sustainers there is a huge requirement to have information updated and current. Use of portal technology, collaboration tools will allow this information sharing. It may also allow an online troubleshooting capability, help, and configuration management of the infrastructure. Building on other activities such as the JBC collaborative tools evaluation and the Air Force Portal development. This task will allow the development of a collaborative capability for coordination of infrastructure activities.

4. Information Assurance (IA) Support

The need for effective IA measures has been demonstrated many times recently, as a result of virus and hacker attacks. In order to respond to these attacks, the Air Force needs a coordinated effort across all the systems that comprise its Integrated C^2 enterprise. The purpose of this set of tasks is to define and execute that coordinated effort.

Implementation of IA in Air Force systems should be executed in accordance with the DoD Defense in Depth concepts and principles in order to protect the entire Integrated C^2 enterprise at minimum cost. In addition, this implementation must be accomplished in a coordinated fashion among all systems that make up the IC^2 enterprise by developing a vision architecture and program roadmaps. Finally, we have to ensure the products that are fielded are adequately tested to avoid interoperability problems and are accompanied with guidance for field personnel on their use.

5. Commercial Technology and Innovation Exploitation

Realizing an integrated C^2 system built on a common (supporting) IT infrastructure depends upon the continuing discovery and exploitation of emerging commercial information technologies and innovative approaches to mission satisfaction. The demands on C^4ISR system developers are increasing rapidly due both to a changing threat environment and the desire to gain military advantage through the use of advanced technologies. However, while advances in IT have great potential, they place great burdens on developers to realize that potential while using immature and in many cases unproven products. In addition, these new technologies must be coupled with older (legacy) systems.

Specifically, exploiting commercial technology and experimental innovation in support of Integrated Command and Control System realization requires investment in eleven (11) primary areas as follows:

- Web technologies
- Personal information services
- COE migration to “all” COTS
- JBI realization
- Portal development
- Wireless/mobile computing-communications

- Advanced knowledge/decision management aides
- Public key infrastructure
- Standards committee influence/participation
- Commercial IT giants liaison (MS, Sun, ...)
- Joint Technical Architecture-Air Force emerging standards identification/analysis/support

Funding Summary. Initial estimates of the annual costs to implement and sustain the above-defined infrastructure elements are as follows:

Table 6-1. *Annual Cost Estimates of Infrastructure Elements*

Infrastructure Elements	*FY02*	*FY03*	*FY04*	*FY05*	*FY06*	*FY07*	*SYDP*
1. Enterprise and domain architectures: development/sustainment	7.0	7.0	7.0	7.0	7.0	7.0	42.0
2. I&I: assurance and certification testing development	24.2	23.5	22.5	22.0	22.0	22.0	136.2
3. Collaborative tools in support of infrastructure definition/development	4.0	2.7	0.8	0.8	0.8	0.8	9.9
4. IA support	7.8	5.8	5.8	5.8	5.8	5.8	36.8
5. Commercial technology and innovation exploitation	23.0	23.0	23.0	23.0	23.0	23.0	138.0
Totals	**66.0**	**62.0**	**59.1**	**58.6**	**58.6**	**58.6**	**362.9**

Dollars in Millions

6.13 Summary

The Air Force's attention to an appropriate structure to acquire command and control systems is far from sufficient. The process, from the attention at Air Staff level, through the PE and panel structure, and most importantly in the actual approach to executing acquisitions once the overly ponderous requirements and program initiation process is finished is seriously broken.

By way of example, the process used by the Air Force on the TBMCS Program was much more painful and traumatic than it needs to be. The process used by a number of other programs in the DoD, exemplified by the GCCS Evolutionary Integration process—where an annual increment of capabilities, already developed in laboratories, ACTDs, etc., in accordance with a set of standards (for example, the DII COE) allowing efficient and rapid integration into an evolving C^2 system (for example, GCCS), best satisfies the desired attributes for acquisition of a major C^2 system. The Air Force acquisition community has not adopted this sort of approach for reasons unknown—in fact the requirement to adhere to standards such as the DII COE has been seen as a costly and unnecessary one. As long as this attitude persists, we will continue to have painful and expensive C^2 acquisitions.

6.14 Summary of Findings

- There is no clear focal point for Air Force C^2, much less for TACCS, at the Air Staff level (and explicitly on the Air Force Council).

- There is no clear definition of the TACCS. CONOPS and operational architectures are inadequate. There is no written statement of a TACCS vision nor is there a prioritized list of desired capabilities.
- A cumbersome formal Air Force requirements process hampers responsiveness to user needs and technology push. AFI 63-123 (spiral development) addresses this issue, but retains the time-consuming process of AFI 10-601.
- Neither AF/TE nor AFOTEC have published a clear statement of policy regarding OT&E of evolutionary acquisition systems.
- The PE structure for the TACCS is fragmented.
- Two large C^2 systems, TBMCS and Air Force Mission Support System, have had significant performance and delivery problems. Precursor systems were originally developed in the CAF and handed off to SAF/AQ and AFMC. Inadequate systems engineering was done on these systems at the outset—the objective was to satisfy severe capability needs.
- The existing Air Force instruction on spiral development does not provide adequate guidance to the field. The practice of spiral development in Air Force SPOs is ad hoc and not institutionalized.
- There is no spokesman or advocate for C^2 infrastructure, such as building a global grid or defining standards for information exchange.
- The Chief of Staff of the Air Force (CSAF) has no reporting system or metrics scheme which provide an assessment of Air Force progress toward accomplishment of an effective TACCS.
- Operators and users, as represented by the AC2ISRC, do not demonstrate an appreciation for crucial infrastructure issues such as the DII COE and Global Grid.
- Combat support elements (for example, supply, maintenance, finance, medical, etc.) are not adequately considered when developing TACCS capability.
- The acquisition structure for the TACCS comprises 2 PEOs and 1 DAC. This fragmentation precludes coherent acquisition.

6.15 Recommendations

- SAF/AQ, AFMC, and AC2ISRC should adopt an acquisition approach for the evolution of C^2 systems such as TBMCS, based on DISA implementation of evolutionary acquisition for GCCS. The major elements are:
  - Establishment of configuration control and integration capability (AFMC, SAF/AQ)
  - The capability to identify (annually) mission application improvements needed in the core TACCS, to identify and evaluate candidate (already developed) applications, and to initiate developments where they are needed (AC2ISRC)
  - Sustainment funding for integration of mission applications into the TBMCS (mostly 3400 and 3080) (AFMC and SAF/AQ)
- SAF/AQ should avoid "big bang" C^2 acquisition programs.
- HQ Air Force should publish requirements guidance which supports the dynamic nature of evolutionary acquisition.
- AC2ISRC should be tasked to accelerate development and publication of the definitive vision, CONOPS and operational architecture for Air Force TACCS.
- CONOPS' and operational architectures approved by the sponsoring MAJCOM Commander must be required before starting development. An adequate CONOPS and operational architecture must be specified as part the Certification of Readiness for OT&E.

- CSAF should enjoin MAJCOMs from organic developments of C^2 systems without consideration of Air Force-wide system impacts.
- CSAF should strengthen C^2 advocacy on the Air Force Council. A single focal point is also needed to work C^2 issues with DoD, Army, Navy, and the Joint Staff. CSAF should also task this advocate with the responsibility of developing and implementing a reporting system which characterizes C^2 readiness and progress.
- The Secretary of the Air Force/CSAF should institutionalize the functions of the Air Force CIO to provide the advocacy and responsibilities required by the Clinger-Cohen Act and to be the spokesman for the C^2 infrastructure.
- SAF/AQ should consolidate the TACCS programs into a single (PEO or DAC) portfolio and under a single Mission Director. SAF/AQ should also develop a capstone PMD to relate and prioritize all those system PMDs which constitute the TACCS. It may also be useful to take the following actions:
  - Establish metrics to measure the effectiveness of the current PEO management system as opposed to the DAC having C^2 system responsibility
  - Stabilize assignments of PEO/PMs to match milestone/delivery achievements
- AF/XP, with SAF/AQ and AC2ISRC, should restructure the program elements which constitute the TACCS into a relatively small number of individually high value PEs which focus on the nodes of the TACCS, their combat capability interrelationships, and their evolutionary development.
- SAF/AQ should task SEI and ESC to develop a CMM for EA/SD leading to a revised AFI and formal EA/SD training. AFMC should develop and implement EA/SD training for the Acquisition Corps.
- EA/SD demands an integrated effort of not just the operational testing community, but the developmental, contractor and user test communities. AF/TE and AFOTEC should develop, in cooperation with ESC/TE, approaches that enhance and support EA/SD acquisition.The current ESC/TE reinvigoration of T&E should be supported and those ESC programs without formal ESC/TE-approved test plans should be required to obtain such approval at an early date.
- T&E procedures specifically tailored to support EA/SD should be developed and published by HQ Air Force.
- Designate a champion for GCSS-AF, coordinate and approve the lead agency charter amendment, approve resources for this lead agency, establish a single acquisition management organization, direct that all Air Force combat support systems integrate into GCSS-AF and comply with its standards.

Appendix 6A
Acquisition Panel Charter

The Acquisition Panel will:

- Identify the *desired* attributes of an acquisition process to acquire and evolve components of the Joint Tactical Air Command and Control System—with special attention to the decision-aiding system(s) supporting the AOC(s). The principal components of the Joint Tactical Air Command and Control System are:
  - Sensors and sources of data
  - Communication links
  - The Joint Air Operations Center and associated Air Operations and Control Centers (for example, AWACS, Wing Operations Center)
  - Weapons delivery and support systems
- Work closely with the System Definition Panel to ensure the operators' needs are addressed.
- Document the current Air Force acquisition process being used to acquire systems such as TBMCS. Investigate alternate acquisition processes, DoD, and other (for example, commercial), which may be more appropriate for acquiring the TACCS. Evaluate these processes against the attributes described in first bullet above.
- Describe an appropriate acquisition process to acquire and evolve the TACCS—including incorporating the JBI concept.
- Recommend changes to current Air Force processes to more closely approximate the attributes of third bullet above. Identify near term and longer-term actions required.

Coordinate with other panels where technologies, personnel actions, etc. are needed or recommended.

(This Page Intentionally Left Blank)

Appendix 6B
Acquisition and Program Management Panel Membership

Maj Gen Eric B. Nelson, USAF (Ret), Chair
Consultant
Aerospace Industry Consulting Services

Mr. Thomas N. Bostelaar
Manager, C^2 Integration Line of Business
TRW Systems and Information Technology Group

Col John J. Colligan, USAF (Ret)
Acquisition Systems Advisor
MITRE Air Force C3 Systems Center

Lt Gen Gordon E. Fornell, USAF (Ret)
Consultant
Dayton Aerospace Inc.

Maj Gen George B. Harrison, USAF (Ret)
Director, Research Operations
Georgia Tech Research Institute

Dr. Mark A. Lorell
Senior Analyst
Rand Corporation, Santa Monica

Dr. Kenneth C. Pedersen
Vice President, Advanced Missile Systems
Raytheon Missile Systems Division

Dr. Harold W. Sorenson
Senior Vice President and General Manager
The MITRE Corporation

RADM Ronald C. Wilgenbusch, USN (Ret)
Consultant
RCW Consulting

Executive Officer: Capt Aaron T. Meadows, 5 CCG/CCE (ACC)
Technical Writer: Maj Stefan B. Dosedel, USAFA

(This Page Intentionally Left Blank)

Continuation of Appendices to Chapter 6

Appendix Number	*Title*	*Page Number*
6C	The Current Air Force Acquisition Process for C^2 Systems: A Case Study of TBMCS	Appendices 6-3
6D	GCCS Integration Process	Appendices 6-57
6E	GCCS Mission Applications Schedules	Appendices 6-59
6F	GCCS Mission Applications Abstracts	Appendices 6-61
6G	The DII COE (from the Integration and Run Time Specification, v. 4.0)	Appendices 6-103
6H	GCSS-AF The Way Ahead (Volume 1)	Appendices 6-115
6I	GCSS Capstone Test and Evaluation Master Plan	Appendices 6-143
6J	DODIIS Test Process	Appendices 6-259

(This Page Intentionally Left Blank)

Chapter 7
Linking the Air Force by 2005

7.1 Introduction

The Study was given the assignment to look at the solutions to "link the Air Force by 2005" with specific reference to the difficulty in attacking mobile targets in Kosovo, as well in other recent crises. We established teams to look at the time-critical targeting (TCT) problem generally, as well as the datalink problem in particular, with the goal of reducing TCT timelines from hours to minutes.

7.2 Time-Critical Targeting Timelines

7.2.1 Contributions to Reduce TCT Timelines

Recent conflicts have highlighted the difficulties in rapidly attacking time-critical targets. The timeline from recognition of the existence of a targetable object until the kill is excessively long. Experience in Operations Desert Shield, Desert Storm, and Noble Anvil (Kosovo) showed that timelines of 4+ hours were typical. The goal expressed by the leadership is to reduce the time from target detection to target strike to under 10 minutes from the current multiple hours. The Air Force Scientific Advisory Board (SAB) has identified and prioritized solutions to bring the timeline down to this goal.

Figure 7-1 portrays the current and future timeline for targeting time-critical targets as experienced in Kosovo. Data for the U-2S sensor processing, exploitation, dissemination process was based on analysis of the image analyst and mensuration logs at the Distributed Common Ground System (DCGS) at Beale Air Force Base (AFB) and the 20th Intelligence Squadron at Offutt AFB by Adroit Systems under contract to the Air Force Studies and Analyses Agency. The times attributed to the operational high-level coordination, Combined Aerospace Operations Center (CAOC) nomination, target folder preparation, and attack execution phases were mostly anecdotal information gathered by the SAB from experienced intelligence, surveillance, and reconnaissance (ISR) officers present at the CAOC. The best time case indicated is based on strike missions using an F-15E with a Joint Standoff Weapon from combat air patrol position with target folder information relayed by data link direct to the F-15E pod.

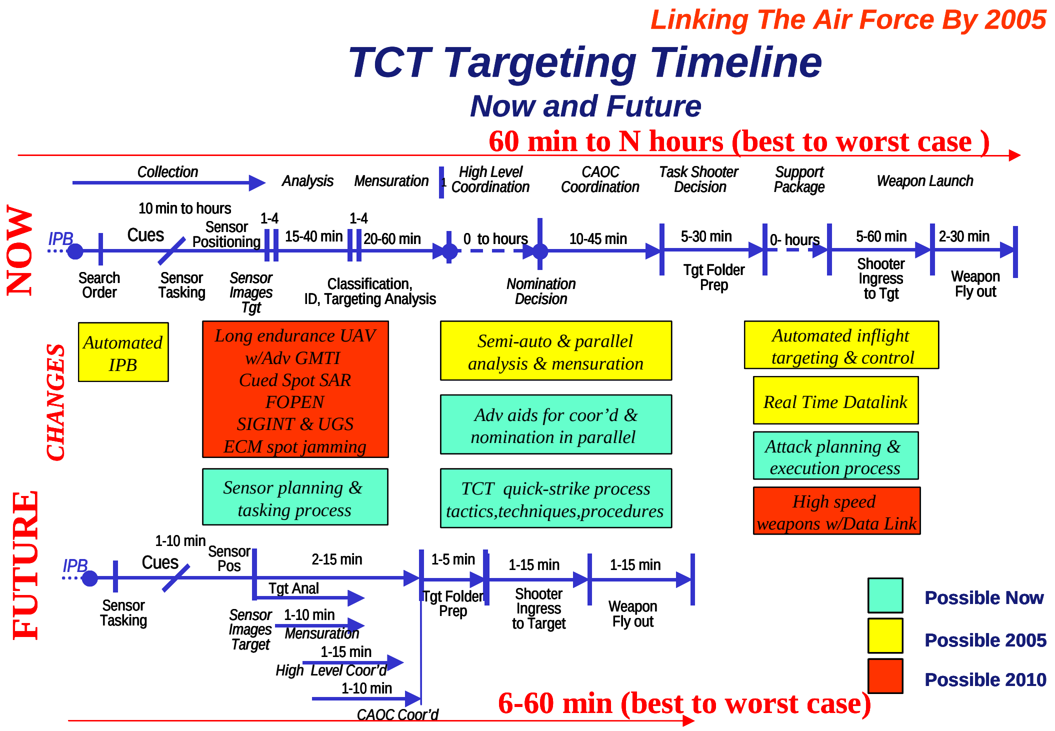


Figure 7-1. *TCT Targeting Timeline—Now and Future*

7.2.2 Major TCT Timeline Findings

The analysis of the time-critical targeting experience led the Study to the following findings:

- Enhanced sensor coverage (time, space, and phenomenology) is essential. High-altitude, long-endurance unmanned aerial vehicle (UAV) systems are sufficiently proven and in many regions can provide performance like low Earth satellites. They are the only near-term answer for standoff (7 x 24) ISR coverage necessary for defense against time-critical targets.
- Technology for modular active electronic scan antenna (AESA) ground moving-target indication (GMTI)/synthetic aperture radar (SAR) has been developed under the F-22 and Joint Strike Fighter (JSF) programs and is ready for development and production for surveillance platforms.
- The technology of moving-target exploitation (MTE) tools for target recognition and tracking has achieved significant progress but needs maturing and further demonstration using AESA hardware.
- The combination of advanced GMTI, high-range-resolution target features and interleaved, simultaneous spot (ultrahigh resolution [UHR++]) SAR images from the same platform will revolutionize ISR and significantly reduce the tasking, collection, processing, exploitation, and dissemination over that of current wide-area imagery schemes.
- Foliage penetration (FOPEN) GMTI/SAR ultrahigh-frequency (UHF) radar technology is available for use as a complementary system with a microwave AESA GMTI/SAR system. Significant sharing of common hardware is possible. It is the only system that will provide standoff coverage in forested regions. It requires more maturation.
- Advances in data exploitation (fusion) are required for robust capability. The technology of fusion processes for timely, geo-registered multisensor inputs from satellite, aircraft, and unattended ground sensors has matured. This includes high-resolution SAR/electro-optical (EO)/

infrared (IR) imagery, moving-target indication/MTE radar, signals intelligence (SIGINT), and hyperspectral signatures. Some capabilities are in the pipeline but need testing and fielding (MTE, automatic target recognition), and additional capabilities need to be developed for this focused fusion capability. Currently fielded sensor control and fusion capabilities are inadequate for future Air Force operations in timeliness, accuracy, and completeness. There are some emerging fusion (GMTI tracking, all-source track fusion) and sensor tasking/management capabilities (multi-asset synchronized planning) that offer enhancements.

Although these are still short of ultimate needs in fusion and control and in their ties to dynamic planning and execution. Presentation and visualization of fused info-products is a neglected area and there exists no organized effort to codify or quantify what capabilities are available for fusion. Codification and quantification are essential in order to assess areas for further science and technology investment and to determine needs for new or augmented sensing capabilities.

- The technology that enables automated target mensuration of any imagery with features by co-registering it with a precision digital reference imagery and terrain elevation database has matured. Further reference development will provide target geo-registration to Earth coordinates of a meter or so and significantly change and speed the mensuration process.
- Sensor management problems will be magnified in the TCT context. Semiautomatic tools to aid real-time ISR sensor and platform planning and tasking have lagged.
- Semiautomatic aids and processes to do target analysis, mensuration, coordination, and nomination in parallel are vitally needed and are key to speeding up time-critical targeting.
- Dedicated time-critical target cells and processes are required (tools, tactics, techniques, procedures, training …).
- Battle damage assessment is a comparatively underdeveloped capability within the larger (and itself underdeveloped) area of real-time fusion for operations. Combat assessment tools—that is, tools for combined battle damage assessment and responsive tasking—do not exist except as created individually by operators. This represents an area—namely, fusion of information and dynamic planning—that cuts across standard functional boundaries. Tools and processes to provide coordinated, near–real time combat damage assessment, are needed from all imagery, including SAR and EO, strike aircraft video, ground target motion (or cessation thereof), and pilot reports.
- Use of advanced high-power, high-gain AESA radar systems to provide selective, high-power spot jamming for electronic countermeasures (ECM) support is feasible but requires dynamic sensor/jammer tasking, planning, and management.
- Automated in-flight target folder preparation and update tools and secure real-time data links to strike aircraft are required for dynamic targeting of time-critical targets.
- Continued development of wideband communications beyond line of sight to support remote reachback analysis is needed.
- Intelligence preparation of the battlefield (IPB) is critically important to sensor planning, tasking, exploitation, and geo-registration. The role of IPB is changing from operations planning to the more continuous process needed to support agile and dynamic operations: predictive battlespace analysis to support missions such as time-critical targeting and timely precision targeting information. Based on a worldwide high-precision, digital foundation database of imagery, digital terrain elevation database, digital feature analysis data (DFAD), and other information, it will produce terrain delimitation (probability of route and location of command posts, forces, etc.) as well as precision geo-registration reference.
- There is a critical need for a complete, dynamically updated, accurate foundation data environment that maps the battlespace: ortho-rectified, geo-registered data sets and automated, laborless, database maintenance.

- High-speed weapons with data links for in-flight retargeting are needed for striking critical mobile targets.
- There is no current capability to display how information operations (IO) can affect the battlefield and how such operations can offset metal on target.

7.2.3 Sensors and Platforms

The key needed ISR improvement is to have continuously available and readily taskable ISR platforms that can stay within rapid access of the target. High-altitude, long-endurance UAVs could provide 7-day, 24-hour ISR coverage, and an advanced radar could provide all-weather, wide-area GMTI coverage and moving-target recognition as well as simultaneous, interleaved high-resolution SAR spot imagery.

Today's ISR systems rely heavily on radar imagery because it is the key source to provide the necessary all-weather, long-range target recognition and precision location. Imagery, especially wide-area imagery, is not rapid either in tasking, collection, processing, exploitation, or dissemination, not only because of the very high bandwidth required and the huge data files to be searched, but, more important, the very difficult problem involved in machine image recognition and analysis. Despite 30 years of research and development in machine target recognition and the tremendous increase in computer power, we have not achieved automatic wide-area image analysis capability and have just begun to achieve modest semiautomated tools to aid expert human image interpreters. The excellent work done over the years in automatic image interpretation and target recognition has convinced the community that goals such as rapid automatic scanning of 100 square kilometers (sq km) per minute of even high-quality imagery (NIIRS 6) is still many years away. Today it takes at least an hour to analyze even small 10-square-kilometer spot images and provide validated target information and mensurated target coordinates.

7.2.4 Advanced AESA GMTI/SAR

New advanced GMTI/SAR sensors offer significant breakthroughs in real-time detection, accurate location, and target feature information of moving targets; the breakthroughs can provide the real-time cue needed to take high-resolution spot imagery needed for the targeting process. This moving-target detection process is the experience of every deer hunter who is often blind to stationary targets but is rapidly cued by even the slightest motion by the deer. Once cued, the hunter is able to focus precisely on the target. Advanced GMTI radar can provide the needed wide area surveillance for moving-target detection and recognition and can provide integrated simultaneous multiple-SAR spot image capability. Unlike imagery, the information from a GMTI radar produces only very modest data rates and can be automatically processed and analyzed in real time.

The advanced radar technology is an outgrowth of the AESA technology developed for the F-22 and JSF fighter programs and now being applied to the radar technology improvement program (RTIP). A modular, scaled variant of the AESA radar will have the power and bandwidth to provide continuous tracking of thousands of targets with automatic recognition of vehicles and military units. It would be capable of simultaneous interleaved GMTI and UHR SAR modes. The dynamic GMTI picture of enemy force movement with simultaneous high-range-resolution (HRR) target features would be able to identify target regions for cued, interleaved SAR stationary target imagery. The estimated GMTI update rates for an area of 5 sq km to 10,000 sq

km is expected to be in the order of 10 to 20 seconds per update for average radiated power of 3 to 6 kW. This would allow simultaneous 1-2 interleaved SAR spot images and hundreds of target recognition measurements without degrading GMTI coverage. The cued SAR spot mode would be capable of improved high-resolution imagery, which would allow rapid image exploitation and target recognition.

The target tracking accuracy and probability of track continuity depends heavily on target acceleration, foliage, terrain shadowing, traffic density, the number of intersecting roads, etc. However, the targeting process can predict some of these factors from IPB terrain and feature data and can schedule updates when targets reach more favorable conditions or cease motion and allow a SAR image. When conditions improve, the dynamic nature of the GMTI/HRR and spot SAR can resolve ambiguities and achieve track or fixed location accuracy necessary for weapon attack.

This significant technical advancement in GMTI radar will provide a major leap ahead in the quality and timeliness of battlefield reconnaissance for the dominant battlespace awareness needed by the battle commander. Rather than just slowly updating moving dots, advanced GMTI radar systems will provide high-update moving-target detection and individual target features, providing much higher-quality information about the nature and dynamics of thousands of moving targets over large areas. The knowledge of vehicle features coupled with high-update track data provides significant information concerning military unit convoy characteristics such as number, type, and mix of vehicles; vehicle traffic and passing activities as a function of road type; mix of civilian and military traffic; indications of roadblocks, bridges, or other traffic constrictions; associated helicopter movement; congregation of vehicles at areas that can be command posts or logistics or refueling areas; traffic sources such as known military installations; and traffic sinks or destinations that can be associated with military units.

GMTI radar high-update detections coupled with rapid vehicle feature information is significantly different from imagery. Finding stationary enemy targets in large areas with high-resolution (at 20 to 200 Mbits per second) imagery can overwhelm the exploitation task and requires large numbers of highly trained human image analysts to exploit it. Advanced dynamic GMTI radar detection and associated high-resolution target feature information is a fairly low-data-rate information stream (hundreds of Kbits per second to a few Mbits per second, depending on vehicle count) that can be processed automatically. GMTI track data lends itself to background automated analysis tasks such as

- Counting the number of vehicles as a function of areas or boundaries
- Determination of sources of target vehicles and their destinations, including the road or path taken
- History of movement over time
- Target evidence and recognition feature accrual and comparison over time, not just a single detection

Microwave GMTI/SAR give all-weather performance but are unable to penetrate foliage. FOPEN radar and/or unattended ground sensors (UGS) and covert radar tags are a necessity if foliage is prevalent and the enemy is skilled in employing camouflage, concealment, and deception. Recent work holds the promise of supplementing the microwave systems with shared receiver, exciter, and processing hardware operating in the UHF band and capable of foliage-

penetration GMTI. Such multirole radars would provide cost-effective sensors for long-endurance UAVs. The microwave frequency would be employed in open terrain, the UHF in foliated regions. The two would cue dynamic management of the two radars and their SAR/GMTI modes.

7.2.5 Intelligence Preparation of the Battlefield

IPB is a process to analyze the battlefield based on a priori collected, geo-registered, and analyzed intelligence, such as imagery intelligence (SAR, visual and multispectral), SIGINT, human intelligence, and measures and signatures intelligence. Future IPB can provide significantly more intelligence support to the commander than is currently possible. Now IPB is driven by operational plan execution. Targeting and target folder development begin with an execution (deployment) order, and shortening the time to employment can squeeze out target folder update opportunities. Future IPB will need to become continuous both before and throughout a conflict and become plan-driven for collection tasking in order to provide continuous database maintenance.

The key to modern IPB is the development of a foundation data environment that includes

- Ortho-rectified and precisely geo-registered imagery data sets
- Imagery from all sources for targeting, geo-location, and feature analysis
- Digital elevation models for targeting, geo-location, and planning
- DFAD, which includes hydrographic and foliage features and cultural or man-made features such as buildings and roads
- Integration of situational awareness data such as military installations and force location
- Time record of changes and the effect of weather

A priori products produced from this foundation data environment include terrain delimitation, which provides analysis of avenues of motion based on terrain nature, foliage, water, bridges, and class of vehicle. It also provides the digital reference information for precision geo-registration of tactical imagery. In addition, tactical imagery is analyzed against the database to produce large object-level changes such as vehicles, new structures, and earth movement. A next level of analyses would be based on current intelligence information on location of forces, bases, logistics, enemy objectives, etc. Based on this analyses, sensor tasking for high-probability regions could be prepared a priori.

Future IPB tools must become automated and continuous for automated, laborless database maintenance and laborless target folder development and maintenance.

7.2.6 The Benefit and Impact of Speeding Up the Target Attack Decision Process

A key benefit of such advanced ISR and IPB input is that the long-endurance, high-altitude radar produces sufficient real-time accurate target location and quality that it could allow the mensuration, high-level coordination, and target nomination processes at the operations center to proceed in parallel with strike approval based on the final rapid, high-resolution image analysis for target identification. This would significantly speed the time for putting weapons on target compared to the current process, which is highly serial out of necessity. In the TCT quick-strike process, it is necessary to provide automated aids and hands-on controls for the warfighter charged with making the decision as to when the available information warrants committing

weapons against a target that has been detected, identified, tracked, and mensurated. It seems intuitive that high-quality, accurate, track data and moving-target recognition data, appropriately fused in a multiple-hypothesis tracking system and aided by interleaved very high-resolution spot SAR images, can provide a significant step toward the confidence needed in order to proceed with parallel commitment of resources. However, the process of making that decision obviously involves a number of variables: the probability that the target is indeed a TCT; the value of destroying that target; the availability of assets to carry out the attack; the existence of enemy defenses that threaten each such asset, and the probabilities of successful mission execution and of asset loss for each; the rules of engagement, such as guidelines on risk of collateral damage, and estimates of the probability of such damage and of its extent.

This closely coupled, parallel process raises an entire range of questions and research areas, such as what information should be presented so that the warfighter can make a decision quickly and correctly, and how should that information be presented in order to provide an information system with the right "handling qualities" for the warfighter? What decision aids are useful for the warfighter? Can this be done in a way that provides the same sense of command authority to the warfighter that digital fly-by-wire systems provide to the pilot?

7.2.7 Recommendations

From the discussion above, and preliminary analyses conducted by the Study, the following actions can result in a significantly shortened TCT timeline and hence are recommended:

- Accelerate production of Global Hawk with improved electrical power (Aeronautics Systems Center [ASC]/RA)
- Develop and produce family of modular AESA GMTI/SAR surveillance radars for Global Hawk as a part of the RTIP development (Electronic Systems Center [ESC]/JS with Air Force Research Laboratory [AFRL]/SN and ASC/RA)
- Mature GMTI radar HRR and tracking techniques (AFRL/IF)
- Develop GMTI FOPEN technology for shared integration with microwave AESA systems of the future (AFRL/SN)
  - Continue research and development of semiautomated tools for target recognition, analysis, image mensuration, and target geo-registration using a digital foundation reference database (AFRL/IF with National Imagery and Mapping Agency [NIMA] and the Defense Advanced Research Projects Agency [DARPA])
- Develop fusion technology for real-time integration of imagery, SIGINT, UGS, radar tags, and EO/IR/hyperspectral (AFRL/IF)
- Continue development of dedicated TCT cell (tactics, techniques, procedures) (Aerospace Command, Control, Intelligence, Surveillance, and Reconnaissance Center [AC2ISRC])
- Analyze the status of techniques and aids to parallel the target exploitation, mensuration, coordination, and nomination processes (AC2ISRC/ESC/AFRL)
- Analyze the status of techniques to speed sensor planning and tasking and attack planning and execution (AC2ISRC/ESC/AFRL)
- Assess the development and role of the Air Force in the foundation database for IPB and mensuration (AFRL with NIMA, National Reconnaissance Office)
  - Assess tools for automated IPB

    – Develop tools for automated in-flight target folder preparation for targeting and retargeting (AFRL/IF)

- Analyze development and application of data links to speed strike planning, pilot folder preparation and update, weapon (AC2ISRC/ESC/AFRL)
- Pursue development of high-speed weapons with data links for in-flight re-targeting (AFRL with DARPA)

7.3 Data Links

The "link the Air Force by 2005" theme provides a direct challenge for the aggressive implementation of datalink program and an indirect challenge for the datalinks through the associated need to quickly attack time critical targets.

In the late 1950s, Air Force air defense fighters depended on Semi-Automatic Ground Environment control systems and datalinked commands to effect continental air defense. First- and second-generation data links were installed in hundreds of aircraft to allow simple messages relaying target data from ground-control intercept sites. In some cases the ground controllers actually took control of the aircraft (or the missile, in the case of BOMARC) and completed the intercept. Over time, the population of datalink-equipped Air Force aircraft shrunk substantially. In the 1991 SAB Summer Study, "Offboard Sensors to Support Air Combat Operations," we strongly recommended that the Air Force realize the importance and leverage of airborne datalink systems and develop, fund, and manage a program to facilitate the transfer of data between weapons systems. Yet, during that same year, Air Force senior leadership declared that datalinks were unnecessary "because of doctrine."[38] By 1996, the Air Force had returned to a point where only 3 percent of aircraft were equipped with J-series datalinks (Tactical Digital Information Link J [TADIL-J] and Variable Message Format [VMF]).

Since that time, the use of Global Positioning System for navigation and weapons delivery has underlined the importance of digital data transfer directly from computer to computer, without the difficult process of voice transfer and computer entry of long number strings, underscoring the need for digital data links.

Over the years, the SAB has repeatedly addressed the aircraft datalink. The past SAB studies have continually reminded the Air Force to expedite the capability for transfer of digital data to and among aircraft. The 1982 SAB Summer Study on "Enhancement of Military Airlift" made a considerable number of recommendations for the transition to digital data and the user of data links on military airlifters. The 1991 Summer Study, "Offboard Sensors to Support Air Combat Operations," noted that "combat aircraft should be equipped with digital datalinks suitable for efficient, countermeasures-protected, low-error information transfer to aircraft systems and aircrews at modest data rates" and recommended the acquisition of the Joint Tactical Information Distribution System (JTIDS), Information Dissemination Management (IDM), and other radios with the appropriate gateway systems. The 1994 Study, "Communications Technology Options for Global Air Operations," noted that "data links are critical to future air operations, imparting critical situational, threat, and target information to the warfighter," further suggesting that the Air Force "view the data transfer architecture as a mixture of cost-effective radio solutions interconnected by gateways."

[38] "U.S. Air Force Chiefs, C^3I Officials Dispute Need for F-15 Datalinks," *Defense News*, 8 July 1991.

Figure 7-2 depicts the notional architecture developed in the 1994 Study. The 1996 Study, "Vision of Aerospace Command and Control for the 21st Century," said, "The Air Force should move away from the heavy reliance on voice communications, especially to the cockpit, and move to more capable linked data systems such as Link-16." The 1997 Study, "Global Air Navigation," noted that "data link transmission provides for a substantial improvement in the effectiveness of information transfer, greatly reducing the errors and confusion associated with voice transmissions. Moreover, the efficiency is similarly much greater, probably to a factor of 100:1, especially those data transfer actions which are associated with the transfer of 'numbers' related with, for example, target location and character."

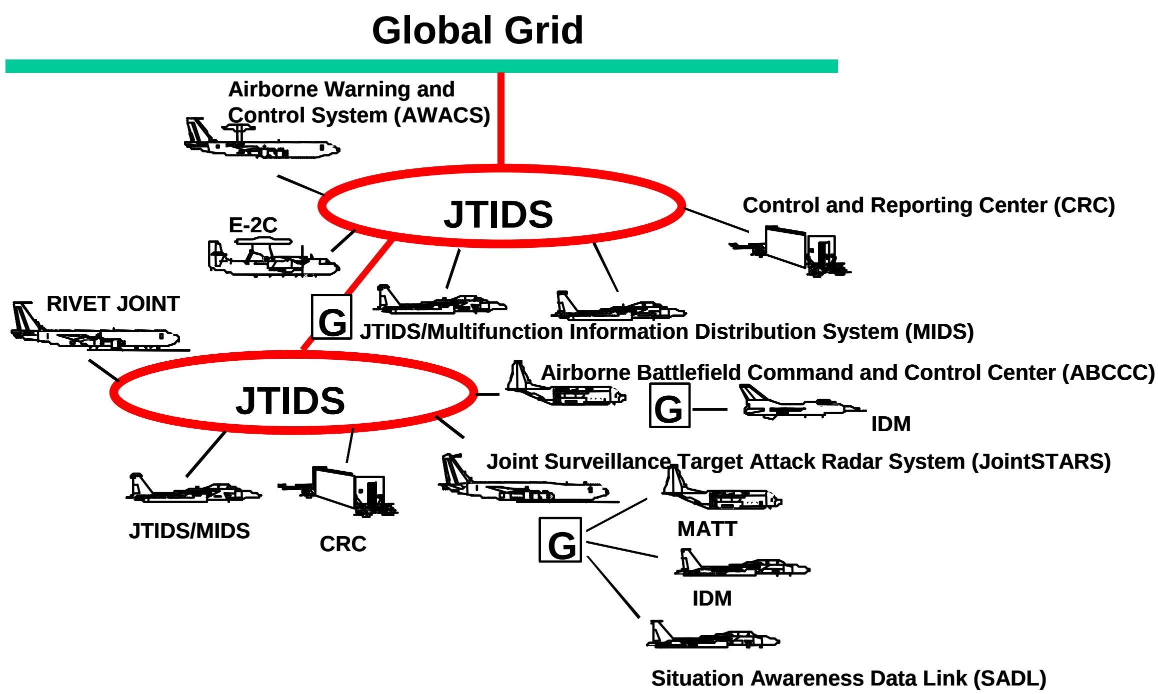


Figure 7-2. *Envisioned Datalink Architecture*[39]

In Joint Expeditionary Force Experiment 2000, we were able to hear the flight lead air crews debrief the mobile target (time-critical target) attack missions with nearly universal success with, and support for, use of the variety of data links on the fighter, bomber, command and control (C^2), and surveillance aircraft involved. The variety of datalink systems was a challenge, but the challenge was met with the Talon Gateway system developed and demonstrated there but the Space Warfare Center. The key message was that datalinks are important to effective air operations, and the Air Force must establish a serious program to provide data transfer capability to and among aircraft.

The historic lack of acceptance of data links has not slowed their development to support special missions. In fact, the number of different data links in use by the Air Force is relatively large. Tables 7-1 thru 7-4 list many of those in current use across the Department of Defense (DoD), of which the Air Force uses a substantial fraction. Table 7-6 illustrates the commonality that is currently planned between Air Force C^2 systems and both combat aircraft and ISR platforms.

[39] Adapted from the 1994 SAB Study, "Communications Technology Options for Global Air Operations."

DoD Directive (DoDD) 4630.5 contains basic policy regarding command, control, communications, and intelligence (C^3I) compatibility, interoperability, and integration, which includes C^3I tactical data links. DoD policy designates Link-16 as the primary tactical data link for all Service and Defense Agency C^2, intelligence, and, where practical, weapon system applications, unless an exception is granted. The policy contained in DoDD-4630.5 expands and reinforces the Assistant Secretary of Defense (C^3I) Common Data Link (CDL) policy memorandum of 13 December 1991, which stated that *"unprocessed, broadband, imagery and signals intelligence data are required to be provided through CDL to intelligence data processing centers. All processed information will be disseminated through Link-16 to permit standardized, interoperable, data link support directly to the operator on the battlefield."*

The Air Force commitment to datalinks has been strengthening, and current plans and budgets reflect the intent to field 3372 platforms (aircraft and command nodes) equipped with J-Series datalinks by 2015. The installation rate funded by the current (FY00) budget (as indicated by the Program Objective Memorandum [POM] submission and reported in the Joint Tactical Data Link Management Plan) is shown in Table 7-5 and Figure 7-3. The challenge presented to this study was to suggest ways to accelerate this plan and to achieve the "linking of the Air Force" by 2005.

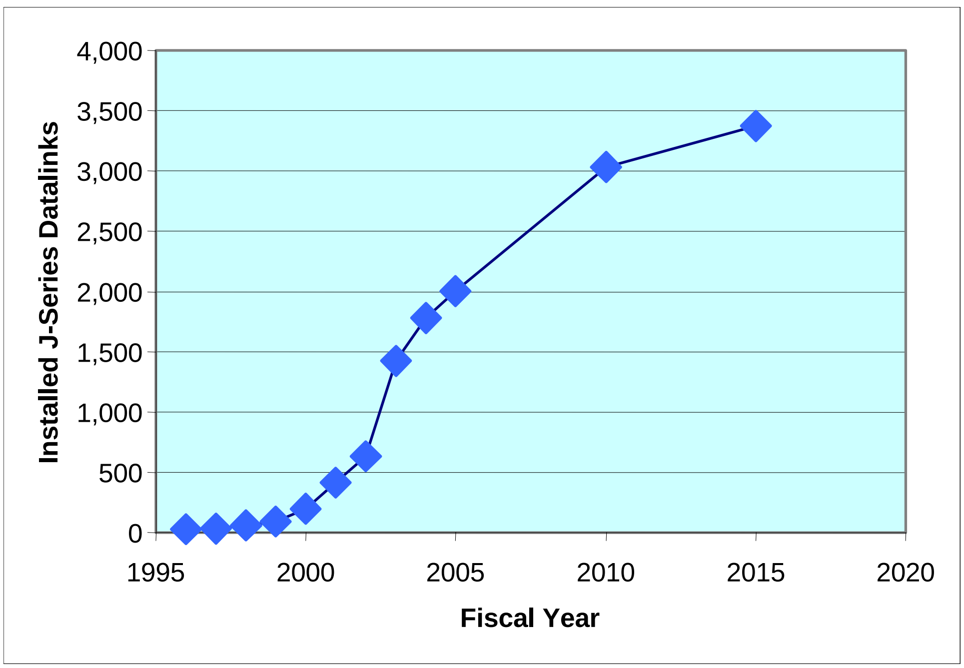


Figure 7-3. *J-Series Datalinks Planned for Installation in Air Force Aircraft (per the Joint Tactical Data Link Master Plan [JTDLMP])*

It was not possible during the study period to address the engineering (hardware and software) issues across the fleet. The study did, however, make it very clear that a dedicated engineer-operational team should devote the extensive time necessary to determine the proper hardware and software concept of operations approach. This detailed analysis by the Air Force is critical to determining the proper approach to gaining digital message connectivity between combat elements. The only viable alternative that we can suggest (and one that is subject to further

investigation and validation) is to install SADL terminals compatible with TADIL-J in 877 F-16 Block 40 and Block 50 aircraft starting in 2002 and to simultaneously develop and field gateways between Link-16 and SADL. This option could allow an acceleration of TADIL-J implementation. When MIDS terminals are installed in these aircraft, the SADL terminals can be removed (and potentially returned to the Army).

If the Link-16/SADL option is implemented, Figure 7-4 illustrates the resulting increase in the number of TADIL-J equipped aircraft from an already accelerated installation schedule (relative to the schedule laid out in the JTDLMP).

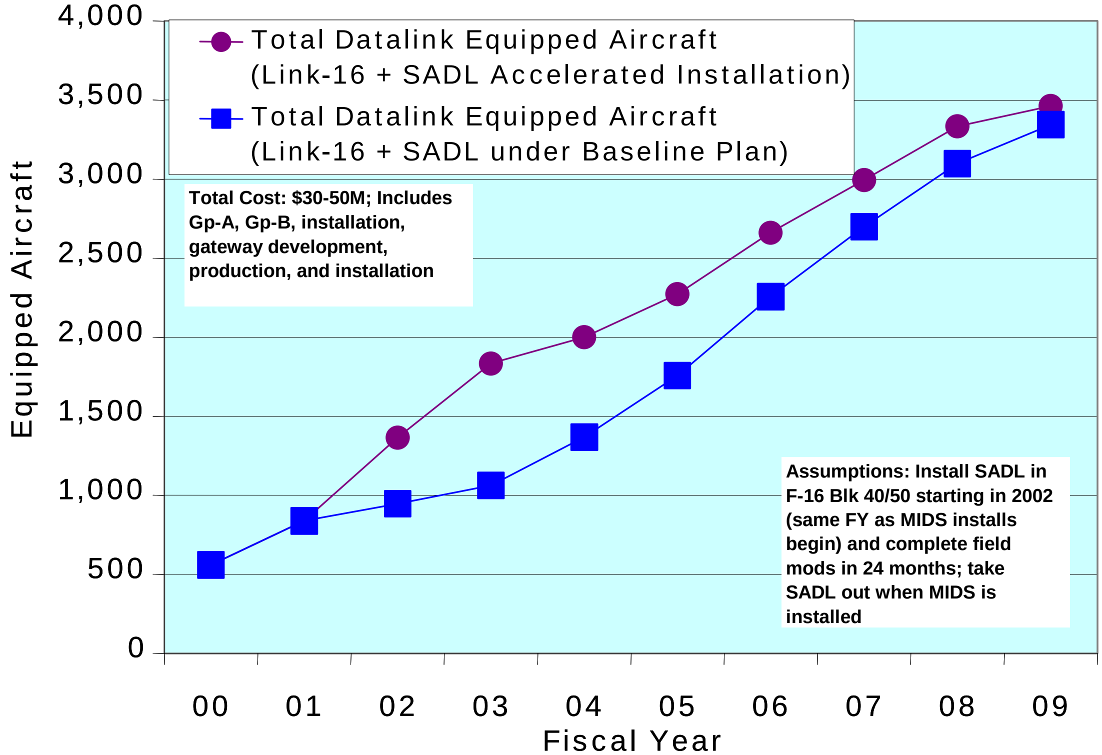


Figure 7-4. *Datalink Equipped Aircraft Under Current and Alternative Installation Schedules*

From a longer-term perspective, there are opportunities to rationalize the collection of Air Force data links. One obstacle to changing out old data links has been the need to maintain compatibility between existing platforms and their ground stations (or among a collection of platforms) while fitting the data links into the space, weight, power, and frequency allocation limitations of existing systems.

The fact that installation of each data link is funded by the platform program rather than by an integrated data link program office has contributed substantially to delays in fielding a fully connected Air Force. One of the conclusions of this study is that the Air Force should establish a single manager for data links and put the budget for all installations in the data link program rather than spreading it across the multiple platform programs.

Table 7-1. *Tactical Data Links Managed by the JTDLMP*

Army Tactical Data Link (ATDL-1)
Cooperative Engagement Capability (CEC)
Forward Area Air Defense (FAAD) Data Link (FDL)
Ground Based Data Link (GBDL)
Interim JTIDS Message Specification (IJMS)
Intra Vehicular Info System (IVIS)
Link 22
Marine Tactical System (MTS)
Patriot Automated Digital Information Link (PADIL)
Tactical Fire Direction System (TACFIRE)
Integrated Broadcast Service (IBS) Note: Tactical Information Broadcast Service, Tactical Data Distribution System, Tactical Reconnaissance Intelligence System, and Near-Real Time Dissemination are planned for migration to IBS, and the IBS data link is planned to transition to the J-series family of messages
TADIL-A (Link-11)
TADIL- B (Link-11B)
TADIL-C (Link-4A)
TADIL-J (Link-16)
Variable Message Format
SADL

Table 7-2. *CDL Family Tactical Data Links Not Managed by the JTDLMP*

Airborne Information Transfer (ABIT)
Advanced Tactical Airborne Reconnaissance System (ATARS) Data Link
Battle Group Passive Horizon Extension System (BGPHES) Data Link
Common High-Bandwidth Data Link (CHBDL)
Guardrail Interoperable Data Link (IDL)
Guardrail Common Sensor System One (CSS1) Data Link
Guardrail Common Sensor System Two (CSS2) Data Link
Guardrail CSS2 Multi-Role Data Link (MRDL)
Guardrail CSS2 Direct Air to Satellite Relay (DASR) Data Link
Line of Sight (LOS) Data Link Implementation (LOS tether)
Lightweight CDL (LWCDL)
L-52M (SR-71)
Rivet Reach/Rivet Owl Data Link
Senior Span
Senior Spur
Senior Stretch
Senior Year IDL
Space CDL
TR-1 mode MIST Airborne Data Link

Table 7-3. *Other Collection Data Links Not Managed by the JTDLMP*

Ku-band Satellite Communications (SATCOM) Data Link Implementation (UAV)
Mission Equipment Control Data link (MECDL)
Radar Data Transmitting Set Data Link
Surveillance and Control Data Link (SCDL)
Tactical UAV Video
UHF SATCOM Data Link Implementation (UAV)

Table 7-4. *Other Non-Collection Datalinks Not Managed by the JTDLMP*

Enhanced Position Location Reporting System (EPLRS)
Position Location Reporting System (PLRS)

7.4 Summary

For the most part, the time-critical target solution does not involve major technological breakthroughs, but rather the dedication and focus to concentrate a few resources and some technical and operational thought on the problem. Today's TCT systems rely heavily on imagery because it is the key source to provide the necessary target recognition and identification and geo-registered coordinates. Imagery, especially wide-area imagery, is not rapid in tasking, collection, processing, exploitation, or dissemination due not only to the very high bandwidth required and the huge data files to be searched, but, more important, the very difficult problem involved in machine image recognition and analysis. The work in image target recognition has to continue, but new advanced GMTI/SAR radar sensors offer significant breakthroughs in real-time detection, accurate location and target feature information of moving targets that can provide the real-time cue needed to take high-resolution spot imagery needed for the targeting process.

The key needed ISR improvement is to have continuously available and readily taskable ISR platforms that can stay within rapid access of the target. High-altitude, long-endurance UAV platforms could provide 7-day, 24-hour ISR coverage, and an advanced radar could provide all-weather, wide-area GMTI coverage and moving-target recognition as well as simultaneous, interleaved high-resolution SAR spot imagery.

The data link problem is long-standing. SAB studies going back to 1991 have continually identified the need for concentrated action to gain and integrate effective digital datalink systems. There are solutions that capitalize on achieving an operational capability for transfer of J-series message sets to attack aircraft. The operational approach to achieving a capability within the deploying Aerospace Expeditionary Forces in the most rapid, cost-effective way possible should be followed. This will happen only if a single point of management is achieved. Clearly, the data link solution consumes money and time, but the tremendous leverage this data transfer capability provides makes the investment crucial.

Linking the Air Force by 2005 will require decisive action on the part of Air Force leadership to address fundamental human factors issues that impact the performance, readiness, and sustainability of present systems for theater battle management. C^2 must be elevated in status and priority to a level consistent with that of other essential weapons systems and warfighting functions. The establishment of C^2 as a weapons system has important implications for Air Force institutions, organization, and processes used to select, assign, train, and equip C^2 warfighters.

"Linking the Air Force by 2005" is critical to conducting air operations against time critical targets. It is solvable if, and only if, the Air Force staff drops institutional and political barriers and addresses the TCT and associated data link issues with an integrated, aggressive approach.

Chapter 8
Technology and Architecture Issues in Implementing the Joint Battlespace InfoSphere (JBI)

8.1 Introduction

Successive Air Force Scientific Advisory Board (SAB) studies have progressively defined the JBI and recommended a program to implement it.[40] The JBI is a powerful *operational* view of information services to the warfighter. The cited studies provide implementation concepts that are carefully grounded in modern information system technology and practice; these concepts establish a basis for moving forward to build a JBI that will provide the foundation for information-enabled warfare.

In the course of this study, a set of lower level technical and architectural issues, as well as some exciting emerging technological opportunities, have surfaced from a variety of sources. In a sense, these involve a *bottom-up* view, traversing layers of an actual JBI that should be invisible to application programmers and users, although they entail some critical acquisition aspects. Among the questions the study team has dealt with are:

1. What is the relationship between the JBI and the Defense Information Infrastructure Common Operating Environment (DII COE)? Given that the DII COE defines a computing platform on which programs that implement the JBI could, conceivably, ride, what should be the evolutionary path of the DII COE itself?[41]
2. What is the right information model (by implication, far more than simply a data model) for the JBI? What is the "object schema" called for in the earlier studies, and how is it to be defined at a level of detail sufficient to allow an engineering team to experiment with it or incorporate it in a spiral JBI development?
3. How should the JBI cope with the immense complexity inherent in an information model that spans all Services, allies, warfighting and support communities, force echelons, and types of operations? As a cautionary tale, the study team was briefed by the Defense Information Systems Agency (DISA) that, of the 11,000 or so data elements in the current C^2CORE model, *partial* joint agreement has been reached on *five* over the course of years of effort, and prospects for further progress are limited.
4. What should the Air Force be doing today, over the next five years, and in the longer term, to establish the information technology foundation of the JBI so that a joint, and fully functional infosphere can be brought into existence as soon as possible?
5. What are the real lessons of the Internet and of commercial projects that have succeeded in providing JBI-like information access, strategic and tactical planning, execution management, and assessment of functions to their users? More importantly, how do these lessons translate to the largely common, but different in important ways, world of command and control (C^2), where

[40] SAB Report on "Information Management to Support the Warrior," SAB-TR-98-02, December 1998; SAB Report on "Building the Joint Battlespace InfoSphere," SAB-TR-99-02, December 1999.

[41] An equally important question may be the relationship of the Department of Defense Global Information Grid (GIG) to the JBI. As currently defined, the GIG spans the entire hierarchy of the information infrastructure that supports future forces and thus overlaps significantly with the JBI. The lower layers of the GIG address the kind of connectivity and networking fabric upon which a JBI will depend, and the higher layers of the GIG model could merge with appropriate views of the JBI. However, this topic is beyond the scope of the present discussion.

requirements for security, reliability, and timeliness may exceed those of commercial applications?

This chapter documents the outcome of an extended discussion among members of the study team and outside experts concerned with information technology (IT) and the JBI. It emphasizes the technical aspects of achieving the JBI and is intended to complement the earlier studies. It also seeks to provide a summary tutorial on the background, status and applications of the primary technologies and concepts of modern IT that bear on the problem. It concludes with a recommended set of actions to evolve the existing C^2 environment to the JBI.

8.2 Summary of the JBI

The following paragraphs give just enough information to provide context for the present discussion. The reader is urged to consult the cited SAB reports for more detail. The JBI is a system-of-systems that collects, integrates, aggregates, and distributes information to users at all echelons. The central premise is that there be a shared virtual information base, implemented through shared access to information provided by the many systems that contribute to the infosphere, and with mechanisms that achieve the often described but seldom seen objective of providing the right information to the right users at the right places and times. The JBI employs four key technologies:

- Information exchange between individual users and the JBI using a publish/subscribe interface in which users send information known to be relevant to the JBI and receive information based on a set of user criteria.
- Transformation of data from multiple sources to a common representation and of data to information to knowledge using elemental processes called fuselets.
- Distributed collaboration via shared, updateable knowledge objects.
- Templates, associated with assigned units, that describe operational capability, information inputs, and information requirements.

Figure 8-1 is the JBI "logo," the standard graphical summary of the JBI's functionality. Around the periphery are the warfighting processes that the JBI supports. Within the oval are three layers representing the broad categories of input, manipulation, and interaction, with specific examples if each. At the core, the JBI employs a Structured Common Representation (SCR) in which one or more object schemas are used to define information. A schema prescribes a set of attributes associated with a given object class, and a specific object instantiates the schema by associating values with these attributes. The schema thus employs metadata to define the information objects which, through publish and subscribe actions, are the lifeblood of the JBI. This lets the JBI be thought of as an object broker which automates the collection of information that has been published, the distribution of objects in response to queries or subscriptions, and the transformation of objects as needed to support collaboration among users.

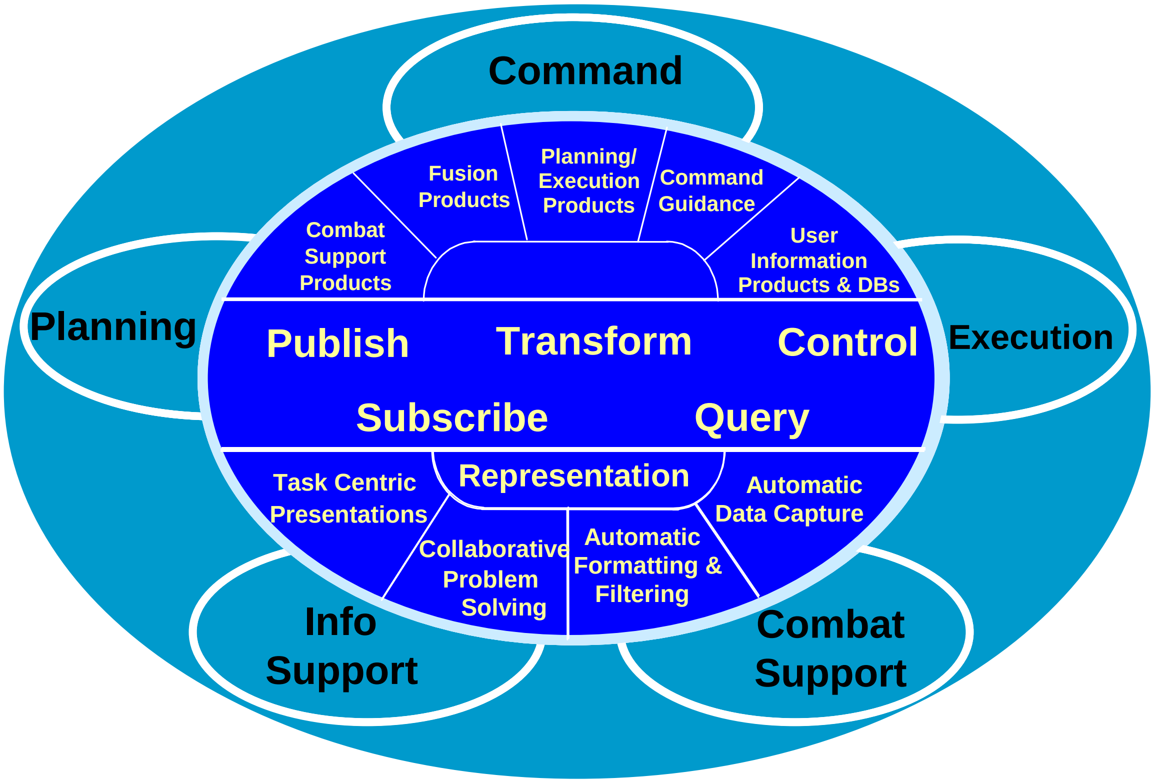


Figure 8-1. *The Basic Structure and Primary Functions of the JBI*

The full richness of the JBI construct includes fusion of data streams to create first information and then knowledge, sophisticated methods of human-JBI interaction, provisions for security and robustness in the face of hostile actions, and many other dimensions of information support to operational forces. The SCR will evolve, and its contents will necessarily be highly dynamic, growing and changing constantly as new data sources, new user templates, and new information objects enter the JBI. However, by centrally managing this complexity, the JBI makes life much simpler for individual users and platforms that employ its services.

As with any complex information system, the JBI requires a variety of views to fully define its structure and functions. For purposes of the present discussion, two top level views are important.[42] A *logical* view describes the information content of the JBI and the information processes that operate on this content. As discussed in detail later, the essence of this view is an information model, and the SCR, the object schemas, the manipulation processes, and the information interfaces are critical elements. A *physical* view has to do with the way the JBI is implemented in the form of applications running on platforms, communicating via networks, and providing a basis for dealing with the rapid evolution of computer and telecommunications technology. Interfaces are still critical, but in this view they take the form of things like applications programming interfaces (APIs), messaging interfaces, and network protocols. The physical view involves both hardware and software and defines the geographically distributed platform that hosts the functionality that creates the logical view as seen by users. A specific

[42] Additional important views focus on security, human-machine interfaces, data management, and other key aspects.

example is the fact that the shared information base, which is treated in the logical view as a single object repository, will physically reside in a variety of data stores associated with assorted C^2 nodes, platforms, and systems.

In the discussion that follows, it is essential to keep clear the distinction between the logical and physical views and to be explicit about which of these JBI dimensions is involved in a given subject. Our approach is consistent with the Department of Defense (DoD) Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C^4ISR) Architecture Framework[43] which defines operational, technical, and system views of an architecture. The first of these describes how a given system or system-of-systems looks to an operational user and responds to that user's needs. The second provides a list of approved standards for implementing the capability, and is currently documented in the DoD Joint Technical Architecture (JTA).[44] The third is the actual system description, or "blueprint," for implementation. Our logical view is primarily an operational architecture perspective, while the physical view is concerned with the system architecture, conditioned by a mandate to make maximum use of the JTA.

Among other things, this distinction between logical and physical views helps to decouple the DII COE, which is basically part of a platform/physical view, from the current vision of the JBI, which takes as its point of departure a logical view of information services to warfighters. Note, however, that even these categories are not perfect, and that a certain amount of gray area remains between them. For example, the DII COE involves the application of DoD's Shared Data Environment (SHADE), which is an approach to data modeling and thus pertains to a logical view. Nonetheless, framing the issues associated with achieving the JBI in terms of logical and physical dimensions is very helpful and provides the basic structure for our analysis.

8.3 The Evolution of Information Technology

The IT on which modern C^2 relies is largely the product of commercial development and applications. However, the DoD strategy for achieving affordable, interoperable, supportable information systems has diverged in several important respects from the philosophy and practices of the private sector. The DoD strategy is embodied in the DoD C^4ISR Architecture Framework, the JTA, the DII COE, the Global Information Grid (GIG), and multiple directives dealing with requirements, acquisition, and interoperability, notably the Chairman Joint Chiefs of Staff Instruction 6212.01B. In seeking the best path to exploit IT technologies and products for information-enabled warfare, it is useful to put the current situation in historical perspective and essential to understand the differences between the DoD approach and that of the global IT community.

8.3.1 Trends in Commercial IT Technology

Over the last several decades, there has been a pronounced trend in information technology for the distinct realms of processing, storage, and networking to come together within an infrastructure that harnesses multiple technologies to deliver services to users. Separate groups and computer science disciplines have concerned themselves with developing higher performance computers, with evolving more efficient data bases, and with designing the data

[43] *DoD C^4ISR Architecture Framework, Version 2,* 18 December 1997.
[44] *Department of Defense Joint Technical Architecture, Version 3.1,* 31 March 2000.

communication networks that allow interconnection of these assets. Today, concepts like "network computing" and "net-enabled data bases" highlight the fact that all three aspects of information infrastructure must be captured in a single, consistent framework. A critical step has been the emergence of the concept of metadata, about which much more is said later in this discussion, because metadata allows the contents of a data store to be more easily accessed through a network transaction. It is the convergence of processors, data bases, and networks in a common process that essentially enables the implementation of information infrastructure as a set of *information services*. The structures in which those services are implemented are hierarchical. That means that they subsume lower level mechanisms and processes in interfaces which conceal (abstract) their detail from users at higher levels. This fundamental concept has the power to make possible information sharing and common processes across multiple classes of users and diverse computing environments.

8.3.2 The Difference in the DII COE[45]

The DII COE, the heart of DoD's interoperability strategy, includes the concept of shared services, but focuses on detailed standardization of execution platforms (computers running specified operating systems, utilities, shared libraries, and the like) to give applications a fully defined operational environment. Indeed, the minimum meaningful level of DII COE compliance is the ability of an application program to coexist with others on a platform without causing conflicts.[46] The basic concept is a set of applications, implementing C^2 systems and functions, riding on a shared common infrastructure that is a point-in-time instantiation of the list of standards contained in the JTA. The components of the DII COE platform are largely commercial-off-the-shelf (COTS) products that have been segmented according to a set of rules so that they can be integrated into the core. The DII COE philosophy is based on the idea that interoperability, sharing of applications, economies of scale, long term supportability, and similar considerations, demand a comprehensive specification of specific products and standards that make up this platform.

The infrastructure then presents itself to an application programmer in the form of APIs, mechanisms like procedure calls for invoking the specific operations of specific versions of specific embedded utilities, and the data model embodied in the SHADE. Applications programmers need to know in detail the specific functions available from the DII COE platform version toward which they are targeted, and subtle changes in those platform details, as the incorporated commercial products evolve, have commonly led to problems in development, integration, and compatibility of applications across multiple DII COE versions.

The DII COE platform is comprised of three shared environments as shown in Figure 8-2: a common operating environment (COE), common data environment (CDE) and common communications environment (CCE). This can be viewed as an approach to the sort of layered architecture concepts that have been successful in many networking applications, as described in Chapter 3 of this Volume. One practical concern is the fact that if it is desired to extend the DII COE platform by adding a new shared component to the core of the environment, a complex and time consuming process of segmenting it and passing stringent compatibility testing is

[45] A fuller discussion of the overall study team's position and recommendations on the DII COE is given in Appendix 4C to Chapter 4, the Technology Panel Report.

[46] Eight levels of compliance are defined, with the lowest dealing with documentation practices; the "peaceful coexistence" referred to here is defined by Level 5.

entailed. Another is that backward compatibility, defined as how many DII COE releases into the future the APIs and common services of an earlier version will be supported, has been limited.

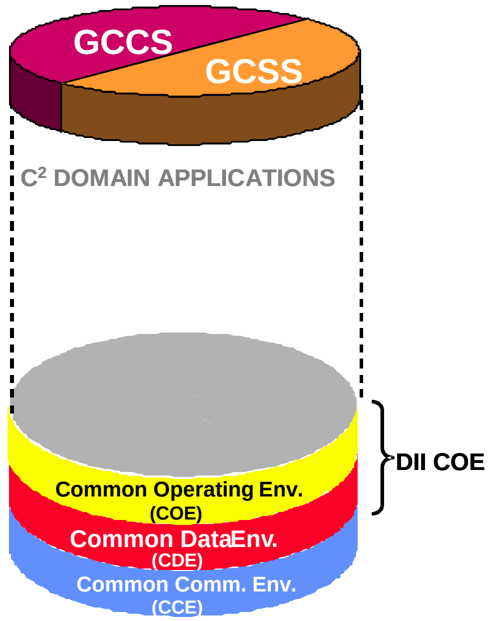


Figure 8-2. *The Basic Layered Structure of the Common Operating Environment*

The current DII COE strategy is widely viewed as being on the wrong side of what is commonly called the "standards vs. standardization" debate. This means that the DII COE focuses on standardizing products rather than on the processes by which information systems interact. Certainly, it is quite different from the Internet model, which largely ignores the details of the platforms involved in a network, concentrating instead on a set of set of protocols that ensure correct information exchange. However, the defects of the DII COE should not obscure the importance of layered architectures and the utility, in some circumstances, of a pre-defined platform that promotes compatibility of applications. We return to this point later in this chapter in discussing the physical implementation of the JBI.

The Internet conceives of the shared infrastructure as a set of *services* presented to a user or application through an interface that hides (except, perhaps, in a performance sense, such as speed of execution) the details of how the service is mechanized. Now, the appropriate standards profile is the minimum set needed to employ the available services. Examples would be standard formats for describing information (think of hypertext markup language [HTML] to describe a web page) and standard protocols for using interaction services (think of the Internet protocol stack). There can still be the equivalent of a COE, CDE and CCE. The difference is in how they are invoked and how they shield users from the inevitable turnover in the technologies and products used to implement them. We propose an approach based on moving from the idea of a COE to that of a Common *Services* Environment (CSE), in which the functions of a COE, CDE and CCE are unified through an abstraction interface.

This approach is consistent with the idea of decoupling the logical and physical views. Something akin to the DII COE, ideally with better provisions for technology refreshment and backward compatibility, would continue to establish standards and guidelines for the physical layers of the JBI. Similarly, the CSE that is the essence of the logical view must be fully defined in terms of rules, constraints, procedures, guidelines and policies, including selective use of standards for such things as publish and subscribe services. The goal is to allow the physical and logical environments to respond to each other's evolution while remaining separated in such a way that changes in the implementation of one do not force changes in the other. For example, as the CSE grows and demands more computational and communications power, it may generate requirements for upgrades to the physical environment. Once again, the Internet provides powerful evidence that a set of services and their associated interfaces can be maintained across many generations of change in the physical platforms on which they ride.

8.4 Information Services for the JBI

The first priority concerns the logical view of the JBI, the way in which an efficient information model is employed to provide information services. For purposes of the present discussion, an information model is defined as:

> A schema for the representation of data, together with the processes which (a) aggregate and associate data to create information, (b) fuse and interpret data to create knowledge, and (c) import, transform, access, and export data, information and knowledge to meet user needs.

Then the CSE presents the JBI to a user as one or more information service interfaces, defined in terms which are transparent to the technology used to implement the underlying platform and intuitively natural for applications programmers to use. Since the essence of the JBI concept is to allow individual users, platforms, and systems to meet their information needs via a publish and subscribe interface to a shared Infosphere, the top level services are simply those described in the manipulation layer of Figure 8-1:

- **Publish.** The InfoSphere receives and processes data or information transmitted by a platform, system or user upon the occurrence of an event which meets the criteria for the action
- **Subscribe/Query.** A user, platform or system obtains information presented by the InfoSphere when the criteria of a subscription or query are met. A subscription is defined by a standing set of criteria; a query is generated by an *ad hoc* information need.
- **Transform.** The InfoSphere activates fuselets that perform the necessary operations to produce required information objects and representations
- **Control.** The InfoSphere monitors and controls JBI functions

8.4.1 Information Models

8.4.1.1 Information in the JBI

The JBI is predicated on the exchange of messages, for example, documents, reports, or commands, within a force. The basic publish/subscribe mechanisms must deal with information integrity, security, quality (including timeliness and level of trust), evolution of missions and technologies, and access controls or user privileges. The information model on which these transactions are based must capture the ways diverse data are imported (including from legacy systems), represented, managed, and exported. Current data modeling approaches cannot meet

the JBI need, but furnish a useful starting point in identifying the types of data involved and their owners and users.

In reality, while it is convenient to speak of "the" JBI information model, there will never be a final, definitive model because the information basis of warfare is constantly changing. Additionally, the very complexity of the JBI information content is likely to demand a number of models, each with its own set of meanings (ontology) and a set of callable service interfaces that are matched to the needs of various user communities. What's needed, therefore, is a *framework* and *process* for the orderly evolution of one or more information models, based on the concepts that have made the Internet so successful and on the most promising technologies for defining and implementing the object schemas and associated processes. Elements of that framework include structure, metadata, and access methods for the JBI information base. For example, standards for metadata definition may be useful in preserving compatibility of information objects across generations of the information systems which use them. It is critical that the information model allow users to tailor information access to their specific needs, for example, by presenting information in formats that are native to their legacy systems and to their tactics, techniques and procedures.

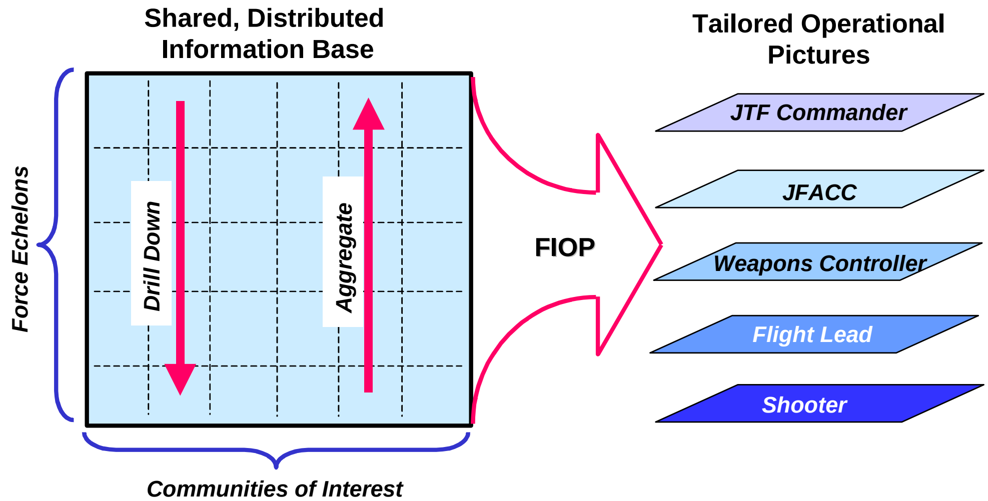


Figure 8-3 *The JBI Shared Information Repository Deals with Many Warfighting and Support Communities and Supports Tailored Information Products at All Force Echelons*

Figure 8-3 illustrates several aspects of the problem. The shared information repository is shown as segmented both by the various communities of interest that contribute to and use the JBI, for example, air, land, maritime, and support organizations, and by the organizational hierarchy, from overall command down to individual warfighters. Implicit in the JBI is the ability to drill down when additional detail is needed and to aggregate data to synthesize higher level views and decision aids. The information base then supports the generation of a Family of Integrated

Operational Pictures (FIOP),[47] with tailored operational views for individual users; a simple example is indicated.

Figure 8-3 also highlights why it will be important to the success of the JBI to carefully define the roles of the individuals and organizations who interact with the shared information base and to make them accountable for fulfilling those roles. In terms of the content of the shared repository, the basic roles are *owner* and *user*. Various areas of content in the shared repository will be owned by specific communities of interest and by organizations within those communities. Ownership is implicit in the publication of data and information into the InfoSphere, whether in the form of updates to data bases or in the form of reports, commands, or other messages. Similarly, a platform, system, or individual who accesses the InfoSphere via subscribe or query actions has an implicitly defined user role. The ownership role is especially important because the integrity and utility of the JBI will, in the final analysis, depend on the ability and effort of data owners to ensure the publication of information with the quality needed by the warfighters that the JBI supports.

Another aspect this view of information services is the expectation that users can and will define their "business processes" in such a way that the flow of information, the nature of required services, and priorities for information support can be articulated and accounted for in the JBI. In the commercial world, where much of the technology and many of the concepts that support the JBI have emerged, it is widely understood that an enterprise architecture must start with the understanding and modeling of business practices and then of the processes that underlie them. From this, the supporting information model can be derived. While a business model may seem foreign to military C^2, there are many parallels; an example would be planning at the strategic, operational and tactical levels. In fact, this is essentially what is meant by an operational architecture, and the increased emphasis now being placed by the Joint Staff and others on defining a Joint Operational Architecture, supported by a set of Joint Mission Architectures, is an important step in laying the foundation for a JBI. Adopting such a "business" point of view will be essential to taking advantage of the new information system paradigm.

8.4.1.2 Current Data Models

A huge amount of effort has been expended over many years in building a variety of existing data models. The Core Architecture Data Model (CADM) of the C^4ISR Architecture Framework is a compendium of data elements intended to provide the basis for defining Information Exchange Requirements in the course of constructing the Operational View of an architecture. The Defense Data Dictionary System (DDDS) is intended to be the repository for data element definitions across DoD. CADM is for building a database to collect architecture info, some of which would be the data models for particular systems. DDDS, on the other hand, is the collection of standard data elements from which developers are expected to choose when building data models that are later captured in a CADM-based database.

At the C^2 level, the most common model seems to be C^2CORE, which is largely an Army data model, although the Army also has its Army Integrated Core Data Model and the Land C^2 Information Exchange Model. The latter is also the North Atlantic Treaty Organization (NATO)

[47] FIOP is the current preferred term for what was formerly labeled the Common Operating Picture and is intended to lead eventually to a single Common Relevant Operational Picture. For information, contact Director, Interoperability, OUSD(AT&L).

reference model known as ADaTP-32 and is due to become a NATO STANAG. Message structures like the Link-16 J-series messages and the US Message Transmission Format could also be seen as elements of a data model. At the bottom of the modeling pyramid, every information system and network has its own data model; an example is the data base design of the Air Operations Data Base defined for the Theater Battle Management Core Systems (TBMCS).

In general, the prevailing philosophy of data modelers in the defense community has been to pursue comprehensive data element definitions that meet the needs of all warfighters. There are two basic reasons why these approaches have been unsuccessful:

- Like any data dictionary, the resulting models tend to be flat, that is, have no hierarchy or other structure, which avoids issues of precedence but makes them extremely cumbersome to use
- They make no provision for tailoring by user communities, and thus bring on the endless debates about details that have, in fact, bedeviled DoD data modelers

The CADM is drawn up as an entity-relationship diagram. There is generally no way in such models to declare domains or to segment the contents to simplify the task of using the content in a particular warfighting context. These models are so huge, so complex, and so difficult to keep current with evolving systems and operational needs that they are destined to fail. On the other hand, hierarchy alone is not sufficient to deal with this level of complexity. The X.500 directory services standard defines a sophisticated hierarchy scheme which has proved, in practice, hard to manage and has thus far failed to solve the problem of efficiently addressing large numbers of network subscribers. This sad history suggests that the problem of dealing with the size and diversity of the JBI information base, even as an aggregation of information from multiple sources, may prove to be the principal obstacle to achieving its promise.

8.4.1.3 From Format to Meaning

A number of technology options have emerged that may help in dealing with this problem. Methods for describing, manipulating and presenting data that were not available in earlier generations are critical to dealing with the tidal wave of data inundating modern C^2 systems. Five essential elements or concepts are format standards, markup languages, metadata, middleware, and abstraction.

Format Standards and Markup Languages. A set of format standards (GIF and JPEG for graphics, RTF and TXT for text, etc.) have emerged by consensus in association with popular desktop applications. These allow different applications (for example, word processors) to share files and thus promote openness and innovation because new and better software can be adopted without losing legacy data or sacrificing interoperability with users of other software. This notion goes an important step further with markup languages which provide a powerful and standard way to describe a data object. The best known of these HTML, which essentially allows the format (fonts, graphics, etc.) that comprise a web page to be described. Then, in principle, any web browser can access the page, and users can freely choose the browser or browsers whose features best meet their needs. HTML even enables a class of utility programs for designing and implementing web pages, eliminating the need to master the language itself. In practice, however, variants of HTML have been promulgated by different vendors that make it possible to build pages that don’t work in all browsers. This is an example of an area where a

widely supported standard would be a good thing, delivering more in the form of interoperability than it costs in the form of limits on innovation.

Metadata. HTML describes an information object (a web page) in terms of *format*. The next logical step is to enable the interface to an object to describe the *content* of that object. The idea of describing content in some standard, widely understood way, formalized by a language, is generalized in the concept known as metadata. Trivially defined as "data about data," metadata has, in fact, multiple meanings in different contexts. In this discussion, it is used in the sense of a prescribed way to define a set of attributes of a data object that allow an information process to efficiently access and act upon that object.

The best known example of a metadata implementation is the eXtensible Markup Language (XML) which allows the definition of "tags" that prescribe the format of a set of attributes that have been defined for the elements of a data store. These tags are conventionally stored in repositories that can be accessed by processes seeking to interact with the data they describe. Furthermore, XML facilitates segmentation of a data store into domains that are of interest to specific user communities by allowing "namespaces" to be established and assigned to individual managers for maintenance and updating. Namespaces allow common XML tags to be reused in various contexts while retaining unique identities. Another important ingredient is the use of Document Type Definitions (DTDs) that define how the author of the XML tags for a document intended them to be interpreted.

In a C^2 context, the operational domains that are managed by namespaces might be things like air operations, meteorology, and intelligence. Clearly, there will be many data items and information objects that are used in multiple domains, and careful design of both the information base itself and the XML tags for such common content will be very important. DoD, through DISA, has established a DII COE XML Registry for tags, data structures, and DTDs, and has assigned Designated Managers for a variety of namespaces; for example, the Air Force CDE staff is responsible for the Aerospace Operations namespace. It would be logical to define namespaces for domains within the JBI, and useful to maintain mappings from these to other metadata repositories such as the DII COE XML Registry.

Taking a track as an example of a data object in a C^2 system, the metadata tag might define attributes such as the category of the target, the coordinates of the state vector defining the target's position and movement, the geographical region in which it is located, and timeliness of the most recent validated sensor report. A user interested in, say, the mobile surface to air missile batteries detected in a specified region in the last 24 hours could use the XML tags to rapidly find and access the details of the relevant tracks. A data store that is "XML-enabled" by defining namespaces, defining attributes, and writing tags is a long way along the path toward being usable in the JBI. With such an interface, the content of a data store is machine-readable, and XML thus allows the implementation of *syntactic* interfaces to data, with attributes of the data presented to an external process or user as the basis for interoperability and efficient access.

This is the fundamental idea behind an XML "wrapper" around an existing data store that allows it to become part of a larger repository. These wrappers are defined by DTDs, but in an application like the JBI, the DTD content will need to go beyond a simple mapping of the various fields in the tags that describe the data. The DTD should also deal with the quality of the data in terms of such attributes as timeliness, ownership and the "pedigree" of the data that

establishes, among other thing, the level of trust accorded to the data's source. Approaching metadata in this way puts the JBI squarely in the IT mainstream and ensures that its data model will be widely understood and easy for application developers to use.

Segmenting the shared information base into domains will never be precise, because certain objects will always be of interest in multiple domains. For example, consider cruise missile tracks. Every warfighting community involved in an operational theater is likely to subscribe to current information on detected inbound cruise missiles. The JBI information model must ensure that the various domains are updated consistently and in real time, even at the expense of some duplication of data. This might be implemented as a replication function in which a central cruise missile track domain publishes updates to appropriate subscribing domains, so that the central track file ensures consistency and eliminates the propagation of false or uncorrelated tracks.

Middleware and Abstraction. Middleware is used in this discussion in a very general sense to designate a broad class of software that mediates between one or more classes of users and a set of information services. Middleware can do anything from establishing an intranet for passing e-mail and scheduling meetings to mechanizing the processes associated with accessing data and scheduling the delivery of products. A fundamental task of JBI middleware will be to ensure synchronization and consistency of content across domains and to resolve conflicts such as inconsistent reports about an object; if necessary, such situations may require alerting a human operator.

Using tools like metadata and middleware, an information infrastructure can implement one or more layers of *abstraction*. This is much like what the developers of structured programming called "information hiding," and the idea is that those details of a process that an external user does not need to know in order to use the process should not be exposed. In defining information services, abstraction layers allow a user (which might be a human operator, an application program, another data store, or something else) to invoke the service in terms that are natural and easy to use. A user who has detected a hostile target might publish the event in terms of "an object of class <SA-20> has been detected at coordinates <x, y, z, t>." Then the JBI would send the track update to every user who had subscribed to this class of target and whose area of interest overlaps a circle of radius n kilometers, where n is the engagement range of the threat system.

The power and utility of middleware will be greatly extended by the use of agent technology. Agents are a complex topic and the subject of a great amount of current research, but the basic idea is that of software entities that contain enough intelligence to autonomously perform functions on behalf of a user, often with incomplete specification of the task. Agents do things like traverse data stores looking for content of interest, not just on the basis of a list of parameters but of "understanding" of the true information needs of the user (which might be an application program) for which they are acting.

Future Trends. Syntactic interfaces using XML represent the current state of the art. They are the basis for an ongoing revolution in electronic commerce ("business-to-business"), process reengineering, and what have come to be known as "enterprise architectures." XML, or an equivalent standard, allows the construction of the attribute/value pairs of an object schema under the JBI. However, the next step in the evolution of information models is beginning to

take shape. A markup language that makes the content of a data store machine-understandable, that is, that presents not only the attributes but the *meaning* of the information, creates a *semantic* interface. This allows the definition of an ontology, a shared basis of meaning about the content of an information store, and is an obvious step in the direction of fully natural interfaces in which a user has no need to know the arcane details of computer languages, data structures, and syntax. The needs of electronic commerce can be expected to drive rapid progress in this area.

Such an interface, using middleware based on agent technology, is being explored by the Defense Advanced Research Projects Agency (DARPA). The associated language is the DARPA Agent Markup Language (DAML), and the goal is to enable agents that not only identify but understand data objects and thus allow great improvement in the quality and productivity of information services that depend on accessing data. Now, for example, a query to the data store could use one or more agents that contain the intelligence to reject data objects whose content is not consistent with the needs of a decision aiding tool that initiated the query. In the language of the JBI, agent technology may prove to be a powerful way to implement fuselets. The full potential of this concept is only beginning to appear. Existing technologies such as XML provide a solid basis for the initial implementation of the JBI, but as the generation of technology represented by DAML matures and is instantiated in tools and products, the full functionality and power of the JBI information model, and the services it empowers, will become available.

8.4.2 The JBI Information Model

With the above as background, we can discuss the characteristics that the JBI information model should possess. The ultimate objective is to present a set of information services to users and applications that are robust, policy-compliant, easy to use, interoperable across communities and systems, and transparently evolvable with the progress of implementing technology. Key attributes are as follows:

8.4.2.1 Domains

Information stores and associated processes must allow segmentation into domains to make manageable the complexity of the data employed by individual communities and systems. Domains also support the need for individual user communities to collect and structure data to meet their specific needs and to exercise data ownership. Information sharing across domain boundaries must be easy to achieve (for example, a submarine may find itself controlling a unmanned aerial vehicle). As noted earlier, XML namespaces and DTDs offer an initial approach to achieving this. Note that the two goals specified here are oppositional—segmenting information into domains makes it harder to share across domains. Moreover, there will never be a clean way to segment data into domains because no two user communities will have the same way of parsing data. There must therefore be accompanying middleware for synchronization of shared information and resolution of discrepancies. It may prove useful for widely shared data and information objects to create centralized data bases which are part of the JBI information model, are not user-defined, and are used to replicate consistent updates into various domains.

8.4.2.2 Structure

Data is inherently hierarchical. Objects such as messages and platforms derive from higher order objects (say, message catalogues and military formations) and imply lower order objects (say, fields and subsystems). Whether or not strict object orientation, involving inheritance, polymorphism, encapsulation, etc., is employed (previous SAB JBI reports say it need not be), a hierarchical data structure is enormously more efficient than a flat one when a search is being performed with less-than-complete specification of the information sought. Other kinds of structure are also useful. HTML documents use hyperlinks to associate content on various pages. Semantic interfaces offer additional possibilities. The point is that the huge, diverse content of the JBI shared information repository must be embodied in a structured representation if it is to be used with high integrity and in real or near-real time.

An important, unsolved technical issue is involved here. The JBI construct implies that the system can associate a unique identifier with an information object and then be able to find out such properties as the object's location, type, and access control permissions. Despite the efforts of bodies such as the Internet Engineering Task Force (IETF) and World Wide Web Consortium (W3C), no such information identification method has yet been agreed upon, implemented and deployed. One system with the desired properties is the "Handle System" developed by CNRI under DARPA sponsorship which has its roots in the digital library community. The JBI must have such a capability, and the responsible developing organizations will need to work with the IT community and, eventually, choose and implement a suitable method.

8.4.2.3 Compatibility with Heterogeneous, Legacy, and Local Data Stores

For practical reasons, it is unlikely to be feasible that the vast array of legacy data bases be translated into an entirely new JBI object schema, certainly not all at once. The information model must provide for wrappers, translators (presumably using fuselets), or other mechanisms that allow incorporation of such data stores and seamless access to them through the interfaces of the information services set. Similarly, there will be circumstances where specialized or privileged data must be accommodated in local stores. As a general attribute, the JBI information model must provide the facilities that allow heterogeneous data stores to be integrated under common abstraction layers and their associated interfaces. Together with segmentation, this attribute addresses data ownership and deals with the operational reality that various segments of the aggregated data environment will be owned and managed by various authorities, each of whom will require appropriate controls over content and not all of whom will agree on all terms.

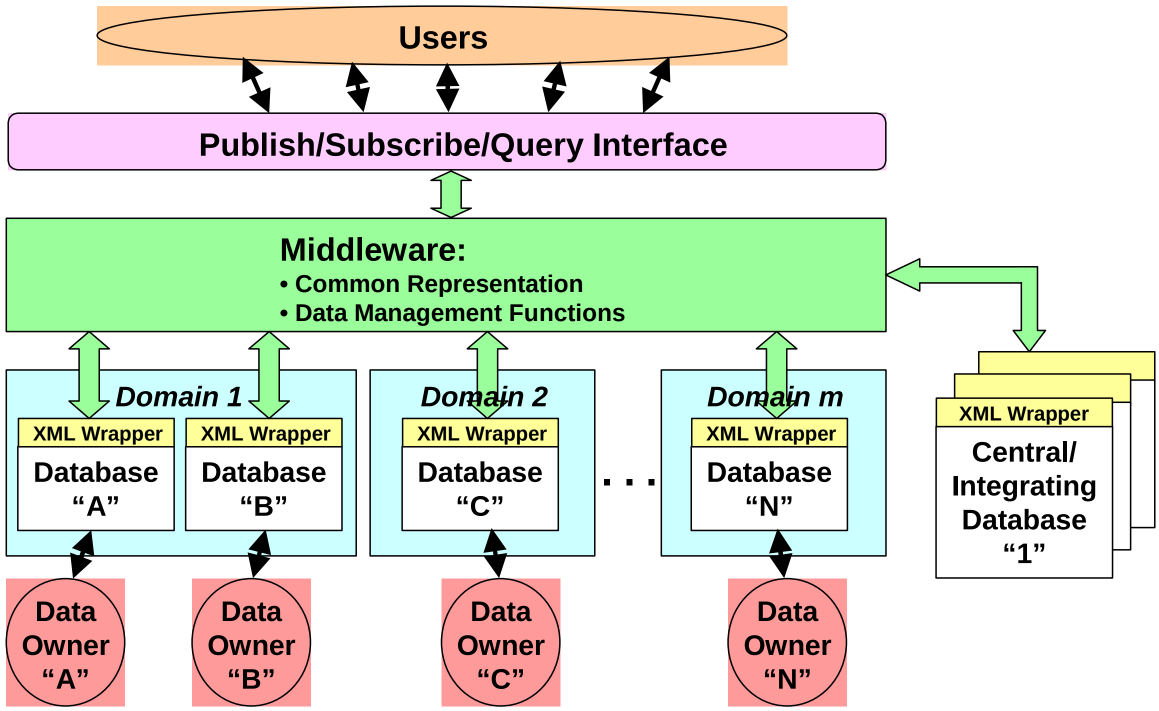


Figure 8-4. *Structure and Features of a Notional JBI Shared Information Base, Drawn to Emphasize the Logical View of the InfoSphere*

Figure 8-4 suggests the nature of a JBI shared database that embodies these principles. This is very much a logical view; the physical instantiation will involve a networked ensemble of nodes and a highly distributed information processing and storage structure. At the top of the logical structure, users see the JBI through a set of information services interfaces for publish, subscribe, and query. At the bottom, the owners of various information sets are responsible for updating the content of their respective domains. Legacy and new databases are XML-tagged; for the former, this provides the necessary wrapper to allow incorporation into the JBI. Middleware is responsible for maintaining consistency across domains; for transforming data to a common SCR; for aggregation, fusion and processing to yield information and knowledge; and for supporting the user interface. As noted earlier, a set of central data bases for data and information that is widely shared across domains may be useful. Again, "middleware" is used here in a very general sense to refer to the many processes that act on data and information from multiple sources and users to knit together JBI functions and services across a heterogeneous and distributed physical implementation.

8.4.2.4 Abstraction

The information model must present the information base through one or more abstraction layers that hide the implementation details. Initially, these will be syntactic interfaces, but semantic interfaces should be implemented as the technology matures. Another dimension of abstraction is the capability of the JBI information model to aggregate data to create information and to fuse and process information to create knowledge. Within the hierarchy of the information model, middleware, especially using agents, can construct information and knowledge objects that are presented to users at the appropriate service interfaces.

8.4.2.5 Management

The JBI will become perhaps the most critical resource commanders and warfighters have available in conducting operations. It will sit at the focus of doctrine, operational priorities, and national policy governing the use of military force. Its performance and integrity will largely determine success or failure. At the same time, it will be one of the most complex information systems ever built. For all these reasons, a critical attribute is the structure that is put in place to manage the JBI, both in terms of its real-time operations and in terms of its development, evolution, certification and integration with supported forces. The related issue of centralized vs. distributed control is discussed in more detail later.

As shown in Figure 8-1, control is a basic JBI service or function. Perhaps a better term, since the JBI will incorporate many systems and information sources, might be “governance.” JBI operations will be largely dictated by policies established at various levels of command; particularly at the operational and tactical levels, the JBI must allow commanders to adjust their policies as the exigencies of an operation dictate. Highly skilled system administrators, communication and networking specialists, and other dedicated personnel will be required to monitor and control infosphere operations and to diagnose and correct problems. As the InfoSphere system-of-systems evolves, continued verification and validation of its hardware and software, including accreditation to handle classified information, will be a continuing challenge. Diverse, and often conflicting, requirements from various user communities must be harmonized and a coherent program implemented to keep the JBI current and supportable. Integration with legacy systems, many of which will present proprietary and incompletely documented interfaces, will be yet another ongoing challenge.

The JBI transfers complexity from individual platforms and systems to a shared information infrastructure. This has great potential to enhance force effectiveness and to reduce the burden on individual users. However, the price to be paid is a very large and complex management task. Within the InfoSphere, there will be functional domains, each with its associated control and management processes. The challenge of dealing with the federated, system-of-systems nature of the JBI while ensuring consistent and robust information services to all users must be treated as a central concern in bringing the JBI to reality.

8.4.2.6 Security

The JBI interacts with many users and systems, integrates the full panoply of operational and intelligence information, and supports the most critical warfighting decisions. The security and integrity of its information are critical to combat success. On one hand, the widespread information sharing that is inherent in the JBI is likely to introduce vulnerabilities, but on the other, centralized control of information may have advantages in providing information assurance. The information model must implement applicable security policies, such as support for virtual private networks, support for multi-level security, and mechanisms for protection against information attacks.

Security is an extremely complex subject which must be a central focus of the evolution of the JBI. The DII COE organization at DISA has placed great emphasis on ensuring the security of the platform kernel, which is one important consideration. Other approaches include the concept of Proof-Carrying Code, being investigated at Carnegie Mellon University, which offers a way to authenticate that a server-provided application is traceable to a trusted source. Various schemes

for user authentication, including the DoD initiative in Public Key Infrastructure may also contribute, but must be compatible with the realities of the battlefield, including the hazard that the credentials of a casualty or prisoner of war may fall into enemy hands. A satisfactory security architecture for the JBI will include functionality allocated at every level from the platform operating system and network manager to trusted applications and user authentication.

Rosenthal and Sciore have developed extensions to Structured Query Language (SQL) that improve controls over access to the content of a data warehouse.[48] This approach appears well matched to distributed data storage and large numbers of users and controlling authorities. Techniques such as this will have to be captured and expanded to achieve a robust security strategy for the JBI. A careful analysis of vulnerabilities and their mitigation in a JBI is still to be accomplished. Security is a very important unsolved problem that needs a great deal of attention and high priority for resources.

8.4.2.7 Consistency and Replication

The JBI information base will be geographically distributed and multiply instantiated. It is essential that the information model provide for replication, synchronization, and consistency enforcement across all locations where common data is stored. It's also important that a common modeling approach be used for data coming from various sources and data provided to applications. An important aspect is likely to be a Transform Library that contains the information on such things as unit conversions (for example, miles to kilometers), file format conversions (for example, JPEG to GIF) and communications protocol translations. Such a library would be extremely useful in the efficient operation of the fuselets that are responsible for the multitude of content transformations required by the JBI.

8.4.2.8 Quality Assurance

In the real world, data will be imperfect, whether contaminated by errors, aged beyond allowable latency limits, missing parameters, or otherwise deficient. The information model must provide for quality checking and allow data to be accessed with appropriate declarations of accuracy, timeliness, trust level of the source, and so forth. When the information model yields multiple inconsistent answers to a query, the appropriate users and system administrators must be informed.

Another essential aspect of quality relates to the source or pedigree of a given information object. The level of trust placed in the source, the inherent quality of the sensor or observer producing the data, the extent to which the source has unhindered access to the event or location being reported on, and similar factors must be accounted for in assigning a quality metric. This is critical when independent or dissimilar information objects must be fused, remembering that the optimum fusion method may simply be to pick the best one and that poorer data may simply degrade the fused result if used indiscrimately.

Quality will depend critically on the currency and accuracy of the metadata in the JBI repository. Metadata is not static because the information objects themselves will be constantly changing. A key function of JBI management will be to ensure adequate provisions for refreshing and revalidating metadata. Tools for the development, editing, and export of metadata are beginning

[48] A. Rosenthal and E. Sciore, "View Security as the Basis for Data Warehouse Security," Proc. Int'l Workshop on Design and Management of Data Warehouses (DMDW 2000), 5-6 June 2000, pp. 8-1 to 8-8.

to emerge for electronic business and other applications and are likely to be important in dealing with this.

8.4.2.9 Additional Services

Over and above the five services identified in the manipulation layer of Figure 8-1, higher order services are likely to evolve to make the JBI more efficient and useful. A "discovery" service would take whatever parameters and criteria a user is able to provide about desired information and conduct an intelligent search for content that may be relevant. A "mediation" service would map content from various domains and in various formats to a uniform interface understandable by all users. A variety of "fusion" services can be envisioned, ranging from association and kinematic merging of track updates to combinations of dissimilar or uncorrelated data to produce indications and warnings messages or to discover previously undetected associations.

8.4.2.10 Interfaces

Last, and most important, the JBI information model(s) must have interfaces that facilitate access to services by each user community. This is the essence of ease of use, because good interfaces make the details of the information infrastructure transparent to operational users. Properly defined and implemented interfaces have far greater impact on the utility of the JBI than the details of information manipulation within the infosphere (as one study participant puts it, "Interfaces are more important than algorithms.") For maximum interoperability, the JBI's service interfaces must be implemented in a language that supports a rich array of functionality. The best example today is probably SQL, with the good possibility that an XML query language will emerge in the near future. Properly implemented metadata supports the generation of connectivity parameters to enable efficient and rapid support for publish and subscribe actions.

8.4.3 Interoperability

A user or platform interacts with the JBI through an interface defined in terms of publish and subscribe actions which invoke the corresponding services of the JBI information model. The JBI interface explicitly allows *ad hoc* queries and might logically be extended to include such things as attachments to messages and references to information locations. This is the essence of interoperability in a JBI world—each participant deals with a single, well-defined information provider instead of with a combinatorially complex set of interfaces to other participants. The interface can be thought of in terms of an interface control document (ICD), since all essential details of the interaction must be defined, but is fundamentally different from the traditional definition of an ICD. Instead of the detailed prescription of signals, bit definitions, and timing relationships of a classic ICD, the JBI interface consists of the information service interfaces, protocols for the communication services employed, and protocols for security, network management, and other aspects of JBI access.

The interface is hierarchical. As the JBI information model evolves to higher levels of abstraction, the top level comes closer to natural language. Here, it is easy to implement both command policies for information dissemination and individual user information needs. At lower levels, details of the information and data structures, the communications channels, and the implementation of security procedures must be dealt with by system designers. At every level of the interface, the guiding principle is a fully open, flexible, Internet-like model of interaction that

uses appropriate public standards where they apply and defines new ones as needed. The choice of standards for publish and subscribe will be especially important.

8.4.4 Centralized vs. Distributed Control

There is an inherent tension in the JBI construct between centralized and decentralized control. From the perspective of commanders and their forces, it is essential that the JBI be controlled in such a way that the quality and consistency of information is assured, command policies are uniformly applied, and a fully defined interface is presented to every user. From the perspective of the system developer, centralized program management of such a large and diverse system-of-systems, built up by the incremental incorporation of many kinds of legacy and new components, is almost certainly unworkable. Put simply, the challenge is to make the logical view appear as a single, fully integrated information services provider while providing for decentralized execution of the physical implementation.

The solution will emerge as the JBI evolves, but some general principles can be defined. There will have to be centralized control of the JBI operational architecture, especially the definition of the services interfaces presented to users. There will also have to be mechanisms for implementing command policy, for example, for "pushing" certain messages to specified recipients. Similarly, the JBI must establish global rules and conventions for the participation of incorporated components. An example of this is the DTDs that define the SCR, providing a common information representation that all information providers must support. Other globals will involve rules for access privileges, definitions of information quality metrics, and any other JBI aspects that apply across the involved platforms, systems and users.

On the other hand, data ownership, interface tailoring for individual users, maintenance of individual JBI components, and the like require distributed control of important JBI features. The next section of this discussion addresses the physical view of the JBIs and some practical considerations involved in building it, which also call for decentralized management. The tension will be resolved by allowing decentralized implementation of the JBI under the operational architecture and a set of global rules.

8.5 Physical Implementation of the JBI

The logical view of the JBI establishes what it looks like to warfighters and, thus, how it contributes to information-enabled operations. However, the physical view is what chiefly determines the feasibility, complexity and cost of actually building the infosphere. Ultimately, the JBI is created by computers and software, networks and data links, human-machine interfaces, and other assets which instantiate JBI information services and their interfaces. As the earlier JBI studies have stressed, this platform environment must be efficiently designed and effectively managed if the goal of seamless, reliable information support to warfighters is to be achieved.

A number of factors make the JBI a formidable undertaking. It must scale effectively to meet the needs of a wide range of force packages and missions. The turnover of technology and products and the practical constraints of system acquisition mean that the JBI platform will be heterogeneous and will continuously evolve. The JBI will be hosted on many types of computers, operating environments, and networks, varying from platform to platform and node to node. Many pieces, some new and some legacy, must be integrated and must function

cooperatively within operational timelines and with the requisite continuity, reliability, security, and quality of service.

It bears repeating that one of the keys to success will be to decouple the logical view with its services and user interfaces from the evolving physical view or platform. In keeping with current best practices in the IT world, the logical view of the JBI must be captured in an operational or functional architecture that is independent of any particular implementation. Then the physical view is documented in hardware and software architectures that define specific instantiations at various nodes within the InfoSphere. This concept makes it easier to deal with such issues as the use of information exchange protocols as the primary means to achieve interoperability and the proper role of the DII COE in helping to establish a suitable platform foundation. We first discuss some aspects of the execution platform and then address an approach to assembling the JBI as a system, or confederation, of systems

8.5.1 Platform Architecture

8.5.1.1 A Role for a Standardized Execution Platform

An infrastructure defined by the DII COE model may well be a useful tool in the C^2 system developer's kit bag. For reference, Figure 8-5 is the standard DII COE model showing the elements of the environment. Continued DII COE use will be more viable if DISA implements improvements to their DII COE strategy as briefed to the study team. Important steps would be to (1) move to completely COTS kernels, and (2) allow commercial procedures (sometimes called "logo certification" since this allows a vendor to put the appropriate logo on a product) to be used to satisfy at least Level 5 compliance certification.[49] A system developer who finds such a platform a good match to requirements, a way to economize on development, and a way to get instant interoperability in an information space might well elect to adopt it. These are just the sort of benefits the current DII COE aims to deliver. The point is that this would be simply an option for instantiation of the platform architecture, not the central strategy.

[49] DII COE compliance below Level 5 is not operationally meaningful.

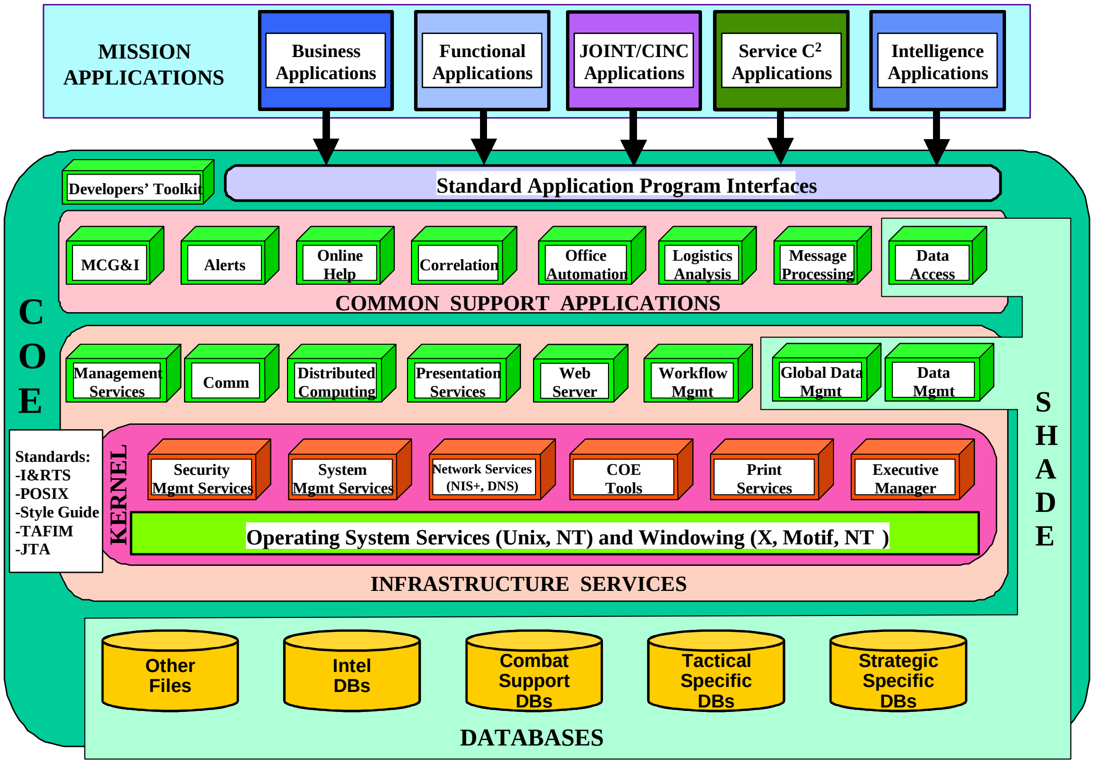


Figure 8-5. *Taxonomy of the DII COE*

The primary route to interoperability remains the information services model and the exchange of messages through the publish/subscribe interfaces of the JBI. JBI services will be provided in a CSE, with each service specified by its interface, including metadata and other format specifications of information, procedures and constraints for invoking the service, and any other required elements. The CSE might well be implemented on DII COE-compliant platforms whose details are transparent to JBI users, following the concept of decoupling of the physical and logical views. In terms of the DoD C^{4}ISR Architecture Framework, the DII COE is an important element of the Technical Architecture while the CSE is a major part of the System Architecture and mechanizes user requirements from the Operational Architecture.

8.5.1.2 Thin Client Networks

The history of multiuser information systems, exemplified in C^2 systems like TBMCS, is one of linking user workstations[50] on a local area network in a client-server environment. In a client-server environment, servers are used to store and manage files, provide a gateway for e-mail and file exchanges, monitor and fine tune network performance, and perform other system administration chores such as managing user accounts and controlling access privileges. The primary applications reside on the workstations, although to save license fees an organization may purchase a limited number of "seats" and control the number of copies of a program that are downloaded at one time for use on workstations.

[50] Workstation is used here in its generic sense, not just to mean a high end processor used for functions such as computer-aided design.

There is a widespread trend in information systems generally to centralize network functionality on powerful servers and to transform workstations into access devices which implement tailored interfaces to network services for individual users. The idea is usually called a “thin client.” This could be seen as a throwback to the early days of networks when “dumb” terminals logged on to a mainframe that did all the computing and storage. It can also be criticized on the grounds that it makes an organization even more vulnerable than it is already to server crashes, network outages, and other single point failures. However, the thin client approach has powerful advantages. Maintaining consistency of shared data, common configuration of shared applications, common and fully enforced access controls and intrusion defenses, and other system-wide features is easier. A thin client network can be simpler to certify for classified processing since workstations now have fewer capabilities to support malicious behavior like communications outside the firewall. In general, the information technology community seems to be moving in this direction, and many military systems are exploring the feasibility and benefits of the thin client concept. [51]

Clearly, the thin client model pertains in large measure to a logical view since it deals with how services are provided to users. However, it also has major physical implications since it drives such things as the nature of the platform employed by a given user, the capacity of the client/server network, and the choice of security mechanisms.

Shared information services are at the heart of the JBI concept, and thus a network of powerful servers and thin clients looks like a good fit. However, care in implementation is essential. A fighter must still be able to perform its mission even if disconnected from the JBI by communications failures or hostile countermeasures. Mission planners, weaponeers, and intelligence analysts must be able to work through outages in the networks and server farms of an air operations center (AOC). Careful system engineering is required to map functionality onto servers, workstations, weapon systems, and all the other nodes of the platform environment and to ensure robustness under real world conditions.

8.5.1.3 Network Computing

With the concept of thin clients comes that of network computing. Related terms are web-enabled applications and data bases and application service providers. In each case, the idea is that a server makes data, applications, libraries and any other services required by a user to perform a function available over a network. Web-enabled data bases using XML have rapidly become the dominant technique for information sharing in such areas as business-to-business commerce. Web-enabled applications promise to make greater functionality available to users. The economic argument is that license or use fees will be smaller than the outright purchase cost of software. A relatively small set of standards associated with the basic Internet model, together with a shared programming language, are the basic enablers of the concept.

The primary implementation of web computing today uses Java, developed by Sun Microsystems. Java is a programming language, but more importantly, it is a client-server paradigm in which a virtual machine is created on a user workstation which then executes applications from the server. Since the virtual machine is (in principle) identical regardless of the computer or operating environment that hosts it, Java applications are (in principle) universally sharable. There are issues with execution speed in real time applications because the

[51] The study team saw an example in use aboard the 3rd Fleet command ship, USS Coronado.

normal Java mode is interpreted, vs. compiled, meaning that the workstation must do multiple calculations for each executed instruction, but these may be overcome with time. Java is widely taught in schools and shows signs of becoming the primary programming environment, especially since it has features that overcome limitations of earlier languages like C++. It is therefore possible that network computing using Java will be a major feature of the JBI platform environment.

8.5.1.4 Component-Based Architecture

A promising approach to the integration of a platform from a variety of products is the notion of treating software elements as components with fully defined interfaces that can be plugged into an operating environment. This can, in fact, take the form of defining metadata about a component. By encapsulating the functionality a component delivers and allowing access to the services it provides only through this well-defined interface, conflicts with other components can be minimized and the process of invoking component services through an interface can be simplified.

8.5.1.5 Communications

The essence of the JBI is the exchange of information within the InfoSphere and among users. This depends on robust, timely data communications through a set of links and networks that form a common communications environment. This is therefore a critical element of the JBI platform environment. One of the key functions of the JBI is to manage the connection fabric and the traffic on it so as to best satisfy the service requirements of users.

Two important concepts here are "spontaneous" or "plug-and-work" network configuration and self annealing networks. The first of these means that an eligible user can join a network simply by connecting to it; practical details such as address assignment are automated. In the Jini construct, developed by Sun as the networking complement to Java, a service wishing to join a network registers with a "federation" through a "lookup service," and clients find these enrolled services by Java type from the lookup service. The associated code then moves to the client from the lookup service like any network application. In a self annealing network, service is maintained or restored after failures or hostile action by a network control function which establishes links and routes traffic based on a set of rules and the available communications paths. In any case, it is essential that the nodes of the infosphere and its users be connected by high capacity, redundant, and dynamically managed communications channels with the responsiveness, security and fault tolerance to maintain services under the stress of operations.

8.5.2 A Migration Path to the JBI

The physical structure of the JBI can be represented as an assembly of mission-relevant systems, which become the components, together with enabling information management services, all passing information to and from one another. Figure 8-6 illustrates a primitive example of a JBI. The small dark outlined ovals, around the periphery of the communications mechanism, called the "Global Information Grid,"[52] represent command and control entities. These software-intensive systems provide a variety of services to users, according to the requirements of the organizations that bought or built them. C^2 systems and supported users and platforms will often

[52] As currently defined by DoD, the GIG is a complete information infrastructure similar in some ways to the JBI, but the communications layer of that infrastructure is what is of interest here.

need to exchange information with each other in order to perform their functions. Such message exchanges have traditionally been accomplished over dedicated circuits or via some form of network that could handle the individual point-to-point information transfers. The GIG encompasses a variety of communications paths, including the Non-Secure Internet Protocol Router Network, Secret Internet Protocol Router Network, and JWICS networks that provide the primary connection fabric of the GCCS.

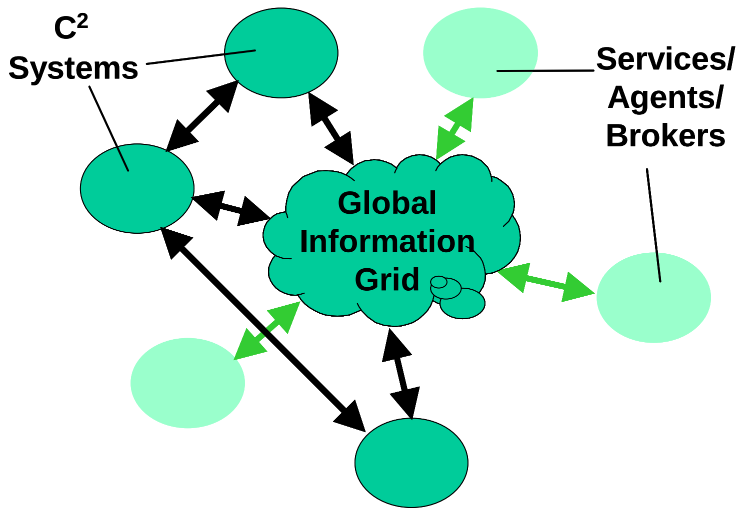


Figure 8-6. *A Top-Level Concept of the JBI as a Collection of Systems and Services Interacting via the Global Information Grid*

For the JBI, these information transfers are augmented by having the individual systems expose (publish) their information in a manner that is interpretable by the other JBI participants. If a system conforms to the protocols that enable information to be interpreted in the JBI, then that system is a JBI client. In addition, since it is essential that the JBI facilitate the migration of legacy systems to the new structure, message exchanges are allowed through a variety of paths. The normal connectivity is via the shared GIG "cloud." However, messages can also be exchanged through "private" channels when performance, security, or other considerations so dictate. Similarly, legacy system-to-system connections may persist when this helps with the assembly and functioning of the JBI. In contrast to the logical view in Figure 8-4, where users are at the top of the hierarchy and the information repository forms the foundation, the physical view in Figure 8-6 emphasizes that users, systems, and the nodes that provide information storage and processing can all be thought of as peers since each is a client of the JBI interacting via the shared network.

The light colored ovals without outlines represent services or "middleware" that enable the JBI to function efficiently and effectively. The individual JBI clients are made aware of one another via one of the JBI enabling facilities that serves as a "broker." An individual JBI client will "publish" information that it anticipates will be useful to other JBI clients. The published information might be raw information, access to an information storage area, or the announcement of a service that the JBI client can offer to other JBI participants. An individual JBI client will also present a "subscription" or "query" for information that it hopes to glean

from the JBI. The broker's task is to match the publishments with the subscriptions and to inform both parties of their mutual existence.

Although similar in concept to search engines used on the Internet, the JBI broker is a bit more sophisticated because it will make the pairwise associations of publishments and subscriptions with some oversight. The oversight may encompass rules for the management of information, for example, command policies. These policy rules may prohibit certain publish/subscribe matches and require others; they may also adjudicate preferential connections for yet others. In other words, the broker provides its services according to policy directives and rules that may be changed from time to time to conform to the commander's intent.

The JBI broker also has some other capabilities. It may prioritize the pairwise matches. These priorities might be established by the commander, but they may also be established through default conditions. Based on the information content to be exchanged over the JBI, the broker may identify some transactions as higher priority than others, and it may provide that priority hierarchy to the communications systems. In this way, the communications can deliver quality of service that matches the specific information content that is flowing throughout the enterprise. As the JBI evolves and technology matures, brokers will become ever more competent, adding services like discovery and fusion as were described in Section 8.4.2.9.

Finally, as alluded throughout the logical description of the JBI, other information management services are incorporated in the JBI. These services, also represented by light ovals in the Figure 8-6, may be introduced to the system by merely incorporating them in the infosphere as additional clients. Services such as data mediation (implied as a capability to achieve the Structured Common Representation), security policy services, temporary or persistent data storage for mission relevant capabilities that are "information storage impaired," portals for preparing special user-relevant information views of the infosphere, etc. may all be services that can be added to the JBI as the level of sophistication desired escalates.

The effect of all this is that each participant or client o the JBI sees the InfoSphere through a *portal* that mechanizes the particular interactions that client requires. These portals are somewhat analogous to personal web pages, and they implement the tailored services interface appropriate to a specific JBI participant. They combine the publish and subscribe actions defined by user-established criteria with actions that respond to central policy, such as "push" of command-dictated messages. They incorporate a mapping of the InfoSphere to make the fetching and storage of information as efficient as possible. As brokers and other JBI functions mature, portals offer users the growing range of services described above.

An important physical attribute of the JBI is the ability to introduce new capability with minimal impact on existing systems. With current system structure, new capability often requires an invasion into the structure of an existing system and disassembly of functions and information so that the new capability can be introduced. With the JBI, as new technology and new communications mechanisms surface, the novel capabilities can subscribe to the legacy information repository and provide new information objects by merely publishing into the JBI. Acceptance and exploitation of the new information will take place through the natural publish/subscribe mechanisms described earlier. The ability of the JBI to scale is assured by keeping the physical interfaces simple, by decoupling dependencies upon critical elements, and by preserving anonymity among participants.

In Figure 8-4, we suggested that the information content of the JBI would be logically organized in domains, with provisions for mapping the content of various data bases into an SCR. An analogous concept applies here in considering the physical structure of the InfoSphere. The various JBI clients are likely to elements of particular functional domains, each contributing data and information, and each responsible for control and management within its boundaries, subject to the overall rules or policies governing the JBI as a whole.

Each JBI participant, or node, in Figure 8-6 could be implemented as an individual system using a layered architecture in which the applications comprising the node's functionality ride on a node platform. The platform might well be defined by a version of the DII COE, facilitating the task of integrating applications within the node. Such an implementation will be assisted if DISA follows through on plans to move the lower levels of the DII COE to purely commercial products and to provide for technology obsolescence mitigation and long-term backward compatibility. The larger scale of interoperability is accounted for by information exchanges through the GIG or over other links and networks, using an Internet-like set of protocols and supporting standards for publish and subscribe. Techniques described earlier in this chapter, including XML wrappers for legacy data bases and web-enabling applications will be central to this implementation strategy.

8.6 A JBI Strategy

There remains the question of choosing and executing the concrete, feasible actions that will power the migration from the current C^2 environment to the JBI. The following steps might form the basis for such a strategy:

- **Sponsor, Define, and Lead an Evolutionary Process.** There are too many unknowns today to define the JBI information model and services in detail. Indeed, as noted above, there is no final model, because the warfighting environment itself is in constant flux. Therefore, what's needed is to involve the key stakeholders in a process of exploring alternatives, gathering data and experience, evaluating technologies and products, choosing standards, and incrementally building and demonstrating the JBI. The success of the Internet is largely based on the fact that its standards emerged from the consensus of communities of interest, and a process like that of the W3C or the more broadly based IETF may be very useful. The Air Force can and should take this on, working with the Joint Staff, Office of the Assistant Secretary of Defense: Command, Control, Communications, and Intelligence (OASD/C^3I), (DISA), the other Services, DARPA, and industry/academia. This is the overarching activity, of which the remaining actions are components.
- **Refine the JBI Information Model.** The views and conclusions expressed in this discussion need to be rigorously challenged, vetted or corrected, and refined through the efforts of experts in the field and through analyses and demonstrations of C^2 systems. The right information model attributes, the right set of implementing standards, the right information assurance model, and the right way of presenting information services to C^2 users and applications are key questions needing thorough investigation, including in operational exercises like the Joint Expeditionary Force Experiment. A key issue is the need to develop a method whereby the system can associate a unique identifier with an information object and then find out such properties as the object's location, type, and access control permissions.
- **Migrate Legacy Systems Toward the Model.** Existing systems intended for continued use should be progressively modified toward compliance with the JBI information model as fast as resources will permit. The goal is to enable these systems as JBI clients. The first steps are to develop XML tags for the data bases or other wrappers that allow legacy data structures to

interoperate in the JBI model, and to web-enable the applications. The other attributes of the model can be progressively implemented as the model matures.

- **Migrate the DII COE.** The Air Force does not "own" the DII COE but can and should be a leading voice for the agenda of migrating toward a services-based model, with standards focused on services rather than products. This will probably entail both constructive engagement with DISA (starting with agreement at the Joint Staff and OASD/C^3I) and the other Services and agencies involved, and work within the Air Force to develop the JBI information model and demonstrate its advantages. A central element of this is to move away from the current DII COE paradigm of exhaustive standardization of platform details and toward an Internet-like strategy. The distributed C^4ISR simulation network that is discussed in Chapter 11 of this report, along with applicable Advanced Concept Technology Demonstrations (ACTDs), actions associated with the "AOC as a weapon system" initiative, updates to legacy systems, and other related efforts should be coordinated to make rapid progress toward this goal. The basic idea is to complement the DII COE platform standardization strategy with the logical model of JBI services and to evolve DII COE toward being an effective JBI platform option
- **Use the Adaptive Battlespace Awareness ACTD as a Vehicle.** The current focus of the ACTD on the Common Operating Picture is appropriate, and any expansion of the ACTD definition to address the JBI information model and produce the evidence to support migrating the DII COE should be straightforward. As the proposed Experimental AOC at Langley Air Force Base (AFB) takes on the role of TBMCS test bed, it should be a participant and might be the logical host site for the ACTD. Other facilities such as the C^2 Training and Innovation Center at Hurlburt AFB and the C^2 Unified Battlespace Environment at Hansom AFB could, over time, be integrated via broadband links into the distributed C^4ISR network to enrich the participation and the resources available to execute the ACTD.
- **Cooperate with DARPA.** The Air Force should exploit technologies from DARPA programs and partner with DARPA to speed the transition of these into JBI implementation. Among other things, this could provide access to the larger IT community and opportunities to influence the content of emerging standards so that they best address military C^2 needs.

8.7 Summary

The future of Air Force C^2, as well as the best hope of achieving the goals of *Joint Vision 2020* and Vision 2020, rest with the JBI. The complexity of this information system is unprecedented, but the technical means to build the InfoSphere are rapidly emerging. The greater problems are likely to be political—reaching a consensus within the Air Force and then across DoD on the "business model" and subordinating individual agendas and spheres of control to the greater good. The JBI will come about through a steady evolutionary process of defining and refining the information model, incrementally adding systems and functionality, validating the design in exercises and operations, and institutionalizing the principles and practices of information-enabled warfare. There can be few more critical tasks facing the Air Force in the years ahead.

(This Page Intentionally Left Blank)

Chapter 9
Summary

9.1 Introduction

There is no doubt in the minds of the Air Force Scientific Advisory Board (SAB) that the Air Force leaders recognize the importance of the effective command and control (C^2) of its forces in achieving success in air operations. There is also a profound recognition that leadership is understanding that air forces engaged in past conflicts have not benefited from the awesome power of an effective theater C^2 system with the flexibility and responsiveness necessary in the dynamic battlespace which technology has brought.

Implementing the necessary changes to the current Theater Air Command and Control System (TACCS) involves much more than a technical (hardware and software) change. In fact, it requires a fundamental change in "business practices", to borrow a commercial term. It requires a top-down revision in thinking and in accomplishing, before any technical changes are made.

9.2 Leadership Commitment

During the course of the Study, the team reviewed the history of deficiencies and fixes to the TACCS. There have been numerous studies, including four SAB Studies in the last five years. There have been organizations and re-organizations, all with little lasting impact on the state of the capabilities.

A fundamental element of the solution must be a commitment on the part of leadership, a commitment to not only initiate actions in supporting the business practice change, but to lay in place a mechanism for high-level review and follow-up to assure actions are fully completed, and that the resulting command and control system allows for evolution as the technology advancements, operational concepts, and world environment dictate.

We are encouraged at the dedication of the current leadership—General Michael Ryan, Chief of Staff, U.S. Air Force; General John Jumper, Commander, Air Combat Command (ACC); and Major General Gerald Perryman—in recognizing the need for action, as well as both the technical and operational issues associated with command and control and the information technology field. Continued attention is encouraged.

9.3 Organizational Change

The management of C^2 has traditionally been spread across combat and support mission areas, boards/panels, and the associated organizational structure without considering the essential need for a C^2 system integrated across the Air Force. Only since the Air Command and Control Agency (AC^2A), now the Aerospace Command and Control, Intelligence, Surveillance, and Reconnaissance Center (AC2ISRC), was established in 1997 has there been any serious consideration of the need to concentrate effort in the area. The AC2ISRC has clearly had great impact on the command and control function, finally getting its arms around the myriad of concept of operations, architectures, programs, program elements, and people.

At the Air Staff level, however, there remains a fragmentation of management of command, control, communications, intelligence, surveillance, and reconnaissance across 8 Panels, 131 program elements, and 4 major two-letter directorates. Moreover, as important as the Center is to the Commander of ACC as well as other major commands, it cannot be effective without a similar consolidation of management at the Air Staff.

Consolidation of the management of C^2 is essential. We cannot expect that the proper management trades critical to a constrained budget will be made in a organizational structure in which management responsibilities are fragmented.

9.4 Defining Command and Control

The official definition of command and control is:

"Command and control is the exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission." (Source: Joint Publication 1-02, Department of Defense Dictionary of Military and Associated Terms)

So, while command and control is a function, the many hardware and non-hardware elements that enable the function must be considered in the management and modernization process.

9.5 Applying Resources

The Air Force faces a critical shortage of funds for operations and maintenance (3400), for system development (3600), and for acquisition (3080). It is not likely that there will be significant relief in the foreseeable future. Thus, the Air Force must assume a level budget, and carefully allocate the funding available to get the most from each dollar. We submit that the current process involving many program elements and no single Panel to represent such activities as the AC2ISRC to assure consideration of the alternatives as well as to prioritize the initiatives, is not an appropriate way to manage limited funds.

Thus, we suggest a greatly reduced number of program elements, and a C^3 Panel in the Board Structure as the surest way to success in solving the many command and control problems.

9.6 Summary

The Air Force Scientific Advisory Board recognizes the substantial pressures on the Air Force to do more with fewer resources. Most certainly, the effective use of command and control in the management and control of air operations could improve the efficiency of the combat forces. The recommendations included in this report are the collective opinion of the study team.

Appendix A to Volume 2
Terms of Reference

USAF Scientific Advisory Board 2000 Summer Study on
Air Force Command and Control – The Path Ahead

BACKGROUND: The Air Force needs to define its command and control (C^2) system in light of recent points of experience in Operations Desert Shield/Desert Storm and Operation Noble Anvil in Kosovo, taking advantage of technological improvements. The Air Force is not on a path today that provides coherence across space, air, and land assets to support the most timely and effective decision making and execution. The USAF Scientific Advisory Board (SAB) and other defense advisory boards have conducted a number of studies over the past decade that bear directly on this problem and form a foundation from which to work. The Board is now being asked to assess the C^2 system and the supporting communication and information systems, to consider technical and process improvements, and to make recommendations on what should be done to "have the USAF linked by 2005" and to build toward the Air Force's long term command and control goals.

Study Products: Briefing to SAF/OS & AF/CC in October 2000. Publish report in December 2000.

Charter:

6. Define the Air Force command and control system with today's capabilities and identify alternatives to enhance it over time:
   - Describe operational C^2 concepts and procedures.
   - Examine functional tasks and consider where these tasks should be accomplished in the organizational construct.
   - Determine connectivity/network requirements for the defined system and improved systems, and identify where today's systems are out of phase or disconnected.
   - Include the integration of intelligence, surveillance and reconnaissance (ISR) assets.
7. Define interoperability (joint and coalition) to ensure coordinated efforts on the battlefield.
8. Identify the technologies that can enhance present and future command and control systems, with near term emphasis on timely and effective communication.
9. Assess the acquisition, programmatic and cost effectiveness issues.
10. Consider the organizational, personnel, training and support consequences.
11. The report should include recommendations on:
    - Defining a specific command and control system with today's assets.
    - Changes in the system possible in the near term with new procedures and technology, with emphasis on "having the USAF linked by 2005".
    - Longer-term improvements consistent with the Air Force's long-term vision for command and control.

(This Page Intentionally Left Blank)

Appendix B to Volume 2
Acronyms and Abbreviations

AADC	Area Air Defense Commander
ABCCC	Airborne Battlefield Command and Control Center
ABCS	Army Battle Control System
ABIT	Airborne Information Transfer
AC^2A	Air Command and Control Agency
AC2ISRC	Aerospace Command and Control, Intelligence, Surveillance, and Reconnaissance Center
ACC	Air Component Commander
ACO	Airspace Control Order
ACS	Agile Combat Support
ACTD	Advanced Concept Technology Demonstration
ADOCS	Automated Deep Operations Coordination System
AEF	Aerospace Expeditionary Force
AESA	Active Electronic Scanned Arrays
AF/DP	Deputy Chief of Staff, Personnel
AF/IL	Deputy Chief of Staff, Installations and Logistics
AF/SC	Deputy Chief of Staff, Air and Space Operations
AF/TE	Headquarters Air Force, Test and Evaluation
AF/XO	Deputy Chief of Staff, Air and Space Operations
AF/XOC	Deputy Chief of Staff, Air and Space Operations, Command and Control
AF/XOI	Deputy Chief of Staff, Air and Space Operations, Intelligence, Surveillance, and Reconnaissance
AF/XOJ	Deputy Chief of Staff, Air and Space Operations, Joint Matters
AF/XOR	Deputy Chief of Staff, Air and Space Operations, Operational Requirements
AF/XP	Deputy Chief of Staff, Plans and Programs
AF/XPP	Deputy Chief of Staff, Plans and Programs, Programs
AFATDS	Advanced Field Artillery Tactical Data System
AFB	Air Force Base
AFDD	Air Force Doctrine Document
AFFOR	Air Force Forces
AFI	Air Force Instruction
AFMC	Air Force Materiel Command
AFOSR	Air Force Office of Scientific Research
AFOTEC	Air Force Operational Test and Evaluation Center
AFRL	Air Force Research Laboratory
AFRL/IF	Air Force Research Laboratory, Information Directorate
AFSC	Air Force Systems Command
AFSOC	Air Force Special Operations Command
AFSPACE	Air Force Space Command
AFSPACECOM	Air Force Space Command
AMC	Air Mobility Command
AMD	Air Mobility Division
AMDWS	Air Missile Defense Work Station
AMOCC	Air Mobility Operations Control Center
AMPS	Air Mission Planning System
AO	Area of Operations
AOC	Air Operations Center
API	Application Program Interface
AR	Acquisition Reform
ASAS	Army's All Source Analysis System

ASC	Aeronautics Systems Center
ASOC	Air Support Operations Center
ASR	Automated Speech Recognition
ATACMS	Tactical Missile System
ATAF	Allied Tactical Air Forces
ATARS	Advanced Tactical Airborne Reconnaissance System
ATDL-1	Army Tactical Data Link-1
ATO	Air Tasking Order
AWACS	Airborne Warning and Control System
BCC	Battle Control Center
BCD	Battlefield Coordination Detachment
BCS	Battle Control System
BGPHES	Battle Group Passive Horizon Extension System
C^2	Command and Control
C^2IPS	Command and Control Information Processing System
C^2ISR	Command, Control, Intelligence, Surveillance, and Reconnaissance
C^2TIG	Command and Control Training and Innovation Center
C^2WAC	Command and Control Warrior Advanced Course
C^3	Command, Control, and Communication
C^4I	Command, Control, Communications, and Intelligence
C^4	Command, Control, Communications, and Computers
C^4I	Command, Control, Communications, Computers, and Intelligence
C^4ISP	Command, Control, Communications, Computers, and Intelligence Support Plan
C^4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
C/S/A	Commander in Chiefs, Services and Agencies
C/JFACC	Combined/Joint Force Air Component Commander
CADM	Core Architecture Data Model
CAF	Combat Air Force
CAIV	Cost as an Independent Variable
CAOC	Combined Aerospace Operations Center
CAS	Close Air Support
CC	Commander
CCE	Common Communications Environment
CCO	Chief, Combat Operations
CCPDS-R	Command Center Processing and Display System–Replacement
CDE	Common Data Environment
CDL	Common Data Link
CEC	Cooperative Engagement Capability
CFACC	Combined Forces Air Component Commander
CHBDL	Common High-Bandwidth Data Link
CINC	Commander in Chief
CIO	Chief Information Officer
CIS	Combat Intelligence System
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CMM	Capability Maturity Model
CoABS	Control of Agent Based Systems
COD	Combat Operations Division
COE	Common Operating Environment
COMAFFOR	Air Forces Commander
COMAFSPACE	Commander Air Force Space Command
COMPES	Contingency Operations Mobility Planning and Execution System
CONOPS	Concept of Operations
CONUS	Continental United States

COP	Common Operating Picture
COTS	Commercial-Off-the-Shelf
CRC	Control and Reporting Center
CRD	Capstone Requirements Document
CRE	Control and Reporting Element
CSAF	Chief of Staff, United States Air Force
CSAR	Combat Search and Rescue
CSE	Common Services Environment
CSP	Communications Support Processor
CSS1	Common Sensor System One
CSS2	Common Sensor System Two
CT	Continuation Training
CTAPS	Contingency Theater Automated Planning System
CUBE	Command and Control Unified Battlespace Environment
DAC	Designated Acquisition Commander
DAML	DARPA Agent Markup Language
DARPA	Defense Advanced Research Projects Agency
DASC	Direct Air Support Center
DASR	Direct Air to Satellite Relay
DCAPES	Deliberate Contingency Action Planning and Execution System
DCGS	Distributed Common Ground System
DCO	Director of Combat Operations
DCS	Deputy Chief of Staff
DDDS	Defense Data Dictionary System
DEP	Distributed Engineering Plant
DFAD	Digital Feature Analysis Data
DIA	Defense Intelligence Agency
DII	Defense Information Infrastructure
DII COE	Defense Information Infrastructure Common Operating Environment
DIRMobFor	Director Mobility Forces
DISA	Defense Information Systems Agency
DMB	Department of Defense Intelligence Information System Management Board
DMPI	Desired Mean Point of Impact
DMRE	Dynamic Mission Readiness Environment
DMS	Defense Message System
DMT	Distributed Mission Training
DOCC	Deep Operations Coordination Cell
DoD	Department of Defense
DoDD	Department of Defense Directive
DODIIS	Department of Defense Intelligence Information System
DP&E	Dynamic Planning and Execution
DT	Development Test
DT&E	Development Test and Evaluation
DTD	Document Type Definition
EA	Evolutionary Acquisition
EA/SD	Evolutionary Acquisition/Spiral Development
EAF	Expeditionary Air Force
ECM	Electronic Countermeasures
EO	Electro-Optical
EOC	Enroute Operations Center
EPLRS	Enhanced Position Location Reporting System
ESC	Electronic Systems Center
EUCOM	European Command
FAAD	Forward Area Air Defense Data Link
FAC-A	Forward Air Control-Airborne

FDL	Forward Area Air Defense Data Link
FIOP	Family of Integrated Operational Pictures
FLEX	Force Level Execution
FLOT	Forward Line of Own Troops
FOA	Field Operating Agency
FOPEN	Foliage Penetration
GBDL	Ground Based Data Link
GCCS	Global Command and Control System
GCCS-A	Global Command and Control System-Army
GCCS-AF	Global Command and Control System-Air Force
GCCS-M	Global Command and Control System-Maritime
GCSS-AF	Global Combat Support System-Air Force
GDSS	Global Deployment Support System
GIG	Global Information Grid
GMTI	Ground Moving-Target Indication
GOTS	Government-Off-the-Shelf
HQ	Headquarters
HRR	High Range Resolution
HSI	Human-System Interface
HTML	Hypertext Markup Language
I&I	Integration and Interoperability
I&RTS	Integration and Run Time Specification
IA	Information Assurance
IBS	Integrated Broadcast Service
ICD	Interface Control Document
IDL	Interoperable Data Link
IDM	Information Dissemination Management
IER	Information Exchange Requirement
IETF	Internet Engineering Task Force
IJMS	Interim JTIDS Message Specification
IKIWISI	I'll Know It When I See It
IM	Information Management
IMS	Information Management System
IO	Information Operations
IOC	Initial Operating Capability
IOP	The Interoperability Panel
IP	Internet Protocol
IPB	Intelligence Preparation of the Battlefield
IPT	Integrated Product Team
IQT	Initial Qualification Training
IR	Infrared
ISC^2	Integrated Space Command and Control
ISR	Intelligence, Surveillance, and Reconnaissance
ISSE	Information Support Server Environment
IT	Information Technology
IT-21	Information Technology–21
IVIS	Intra Vehicular Info System
IW	Information Warfare
IWC	Information Warfare Center
J/CAOC	Joint/Combined Aerospace Operations Center
J/CFACC	Joint/Combined Force Air Component Commander
JAC^2C	Joint Aerospace Command and Control Course
JACAC	Joint Aerospace Computer Applications Course
JAOC	Joint Aerospace Operations Center
JASAC	Joint Aerospace Systems Administrator Course
JBI	Joint Battlespace InfoSphere

JCSAR	Joint Combat Search and Rescue
JCTN	Joint Composite Tracking Network
JDEP	Joint Distributed Engineering Plant
JDN	Joint Data Network
JEFX	Joint Expeditionary Force Experiment
JFACC	Joint Forces Air Component Commander
JFC	Joint Forces Commander
JGAT	Joint Guidance Apportionment & Targeting
JIEO	Joint Information Engineering Organization
JITC	Joint Interoperability Test Center
JITF	Joint Integration and Test Facility
JMA	Joint Mission Architectures
JMPS	Joint Mission Planning System
JOA	Joint Operational Architecture
JointSTARS	Joint Surveillance Target Attack Radar System
JOTS	Joint Operational Tactical System
JP	Joint Publication
JPN	Joint Planning Network
JPO	Joint Program Office
JSA	Joint System Architecture
JSF	Joint Strike Fighter
JSRC	Joint Search and Rescue Center
JSSC	Joint Air Operations Senior Staff Course
JTA	Joint Technical Architecture
JTF	Joint Task Force
JTDLMP	Joint Tactical Data Link Management Plan
JTIDS	Joint Tactical Information Distribution System
JTRS	Joint Tactical Radio System
JV2010	*Joint Vision 2010*
JV2020	*Joint Vision 2020*
KPP	Key Performance Parameter
LCA	Life Cycle Architecture
LD/HD	Low Density/High Demand
LMMS	Lockheed Martin Mission Systems
LOCIS	Logistics Control and Information Support
LOS	Line of Sight
LRP	Limited Response Package
LWCDL	Lightweight Common Data Link
MAJCOM	Major Command
MAP	Mission Area Plan
MASC	Modeling, Analysis, and Simulation Center
MCS	Maneuver Control System
MDA	Milestone Decision Authority
MECDL	Mission Equipment Control Data link
METL	Mission-Essential Task List
METOC	Meteorology and Oceanography
MIDB	Military Integrated Data Base
MIDS	Multifunction Information Distribution System
MLS	Multilevel Security
MRDL	Multi-Role Data Link
MQT	Mission Qualification Training
MS&A	Modeling, Simulation, and Analysis
MTE	Moving-Target Exploitation
MTS	Marine Tactical System
MX	Military Experimental
N/UWSS	NORAD/USPACECOM Warfighting Support System

NAF	Numbered Air Force
NATO	North Atlantic Treaty Organization
NGO	Non-Government Organizations
NIMA	National Imagery and Mapping Agency
NMCC	National Military Command Center
NORAD	North American Air Defense Command
NRO	National Reconnaissance Office
NSA	National Security Agency
O&M	Operations and Maintenance
OASD/C^3I	Office of the Assistant Secretary of Defense: Command, Control, Communications, and Intelligence
OPS	Operations
ORD	Operational Requirements Documents
OSC	Operational Support Center
OSD	Office of the Secretary of Defense
OT	Operational Test
OT&E	Operational Test and Evaluation
OTA	Operational Test Agency
OTS	Officer Training School
PACOM	Pacific Command
PADIL	Patriot Automated Digital Information Link
PE	Program Element
PEO	Program Executive Officer
PLRS	Position Location Reporting System
PM	Program Manager
PMD	Program Management Directive
PME	Professional Military Education
POM	Program Objective Memorandum
POSIX	Portable Operating System for Information Exchange
QRP	Quick Response Package
R&D	Research and Development
RF	Radio Frequency
ROE	Rules of Engagement
ROTC	Reserve Officer Training Corps
RTIP	Radar Technology Improvement Program
S/GA	Situation and Global Awareness
S&T	Science and Technology
SAB	Air Force Scientific Advisory Board
SADL	Situation Awareness Data Link
SAE	Service Acquisition Executive
SAF	Assistant Secretary of the Air Force
SAF/AQ	Assistant Secretary of the Air Force, Acquisition
SAF/AQI	Assistant Secretary of the Air Force, Information Dominance
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communications
SBIR	Small Business Innovative Research
SCDL	Surveillance and Control Data Link
SCR	Structured Common Representation
SD	Spiral Development
SDM	Spiral Development Model
SEAD	Suppression of Enemy Air Defenses
SEI	Software Engineering Institute
SHADE	Shared Data Engineering
SIGINT	Signals Intelligence
SIPRNET	Secret Internet Protocol Router Network
SODO	Senior Offensive Duty Officer

SPAWAR	U.S. Navy Space and Naval Warfare Systems Command
SPINS	Special Instructions
SPO	System Program Office
Sq Km	Square Kilometer
SQL	Structured Query Language
SWPS	Strategic War Planning System
T&E	Test & Evaluation
TACC	Tanker Airlift Control Center
TACCS	Theater Aerospace Command and Control System
TACCSF	Theater Air Command and Control Support Facility
TACFIRE	Tactical Fire Direction System
TACP	Tactical Air Control Party
TACS	Theater Air Control System
TADIL-J	Tactical Digital Information Link J
TAFIM	Technical Architecture Framework for Information Management
TAIS	Tactical Air Information System
TALCE	Tanker Airlift Control Element
TBMCS	Theater Battle Management Core System
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TCT	Time-Critical Targeting
TIE	Technology Integration Experiment
TPFDD	Time Phased Force Deployment Data
TRP	Theater Response Package
TSPR	Total System Performance Responsibility
TTPs	Tactics, Training and Procedures
TULIP	Through Life Interoperability Planning
UAV	Unmanned Aerial Vehicle
UGS	Unattended Ground Sensors
UHF	Ultrahigh-Frequency
UHR++	Ultrahigh Resolution
USAF	United States Air Force
USC	University of Southern California
USCINCSPACE	Commander in Chief United States Space Command
USMTF	U.S. Message Transmission Format
USN	United States Navy
USSPACECOM	United States Space Command
USSTRATCOM	U.S. Strategic Command
UTC	Unit Type Codes
VMF	Virtual Message Format
VTC	Video Teleconferencing
W3C	World Wide Web Consortium
WCCS	Wing Command and Control System
WOC	Wing Operations Center
XML	Extendable Markup Language

(This Page Intentionally Left Blank)

Appendix C to Volume 2
Study Organization

Study Chairman
Dr. Peter R. Worch

Vice Study Chairman
General James P. McCarthy, USAF (Ret)

SAB Military Director
Lt Gen Stephen B. Plummer

General Officer Participant
General John P. Jumper

SAB Executive Director
Col Gregory H. Bishop

SAB Study Executive Officer
Capt D. Brent Morris, AF/SB

Panel Chairs
Concept and System Definition Panel: Lt Gen Joseph Hurd, USAF (Ret)
Interoperability Panel: Dr. John M. Borky
Technology Panel: Dr. Alison K. Brown
Acquisition and Program Management Panel: Maj Gen Eric Nelson, USAF (Ret)
People and Organization Panel: Mr. Jeffery B. Erickson
Vision and Bridging Concepts Panel: Mrs. Natalie W. Crawford

Concept and System Definition Panel

Lt Gen Joseph E. Hurd, USAF (Ret), Chair
Private Consultant

Maj Gen John A. Corder, USAF (Ret)
Private Consultant

Mr. Troy Crites
Sparta, Inc.

Dr. Llewellyn S. Dougherty
Director of Technology
Raytheon Electronic Systems

Mr. Jim Hale
Private Consultant

Maj Gen John Hawley, USAF (Ret)
Private Consultant

Mr. David Hess
AC2ISRC
MITRE

Col Stu Kraft, USAF (Ret)
Director, Business Development
Northrop Grumman/Logicon Technical Solutions

Maj Robert Lanahan
Branch Chief, Future Communications Systems
National Reconnaissance Office

Prof. Alexander H. Levis
Professor
George Mason University

Prof. Christine Mitchell
Professor
Georgia Tech

Maj Robin Morris
AC2ISRC/C2A

Col Wayne Ranne
AC2ISRC/C2X

Col Mike Reavey, USAF (Ret)
Private Consultant

Mr. Skip Saunders
Executive Director
MITRE

Prof. Gene Spafford
Professor
Purdue University

Col Carl Van Pelt, USAF (Ret)
Private Consultant

Lt Gen Ronald Watts, USA (Ret)
President
Leadership Development Services

Executive Officer: Capt Larry W. Norman, Jr., AC2ISRC/C2RO
Technical Writer: Maj Thomas Schorsch, USAFA

Interoperability Panel

Dr. John M. Borky, Chair
Chief Scientist
Tamarac Technologies, LLC

RADM John R. Batzler, USN (Ret)
Senior Warfighting Analyst
Center for Naval Analyses

Prof. Claude R. Canizares
Director, Center for Space Research
Massachusetts Institute of Technology

Mr. Steve Cox
Lead Communications Engineer
MITRE

Dr. Gary A. Federici
Director, Information Operations and Warfare
Center for Naval Analyses

Mr. Thurman (Rich) Haas
Principal Director, National Systems Engineering and Architecture Directorate
The Aerospace Corporation

Lt Gen John B. Hall, Jr., USAF (Ret)
Private Consultant

Dr. Barry M. Leiner
Director
Research Institute for Advanced Computer Science

Lt Col Russel M. Mayes
Chief, Airborne Communications
AFCIC/SYOA

Col John J. Murphy, Jr., USAF (Ret)
Staff Principal Analyst
Aerospace C^2 & ISR Center (ARINC)

Dr. Michael P. Shatz
Leader, Advance Systems Concepts Group
M.I.T. Lincoln Laboratory

Executive Officer: Capt Cristina Huerta, AFRL/VASM
Technical Writer: Maj David E. Bossert, USAFA

Technology Panel

Dr. Alison K. Brown, Chair
President
NAVSYS Corporation

Dr. Thomas A. Brackey, Deputy Chair
Executive Director, Technical Operations
Hughes Space and Communications Company

Dr. Duane A. Adams
Vice Provost for Research
Carnegie Mellon University

Mr. Timothy M. Bonds
Analyst
The RAND Corporation

Mr. John N. Entzminger
Private Consultant

Dr. Gene H. McCall
Chief Scientist
AFSPACECOM

Prof. Alan S. Willsky
Department of Electrical Engineering and Computer Science
Massachusetts Institute of Technology

Maj Kenneth S. Kreit
Program Manager, Large Aperture Spacecraft
National Reconnaissance Office

Advisors:
Dr. Kevin B. Kreitman, Aerospace Corporation
Mr. Richard Metzger, AFRL/IF
Mr. Jay Scarano, MITRE Corporation
Maj Michael J. Estes, C2ISR Center
Maj William Richard, SAF/AQII

Executive Officer: Maj Timothy P. Nickerson, AMC/XPX
Technical Writer: Maj Joseph E. Brouillard, USAFA/IG

Acquisition and Program Management Panel

Maj Gen Eric B. Nelson, USAF (Ret), Chair
Consultant
Aerospace Industry Consulting Services

Mr. Thomas N. Bostelaar
Manager, C^2 Integration Line of Business
TRW Systems and Information Technology Group

Col John J. Colligan, USAF (Ret)
Acquisition Systems Advisor
MITRE Air Force C^3 Systems Center

Lt Gen Gordon E. Fornell, USAF (Ret)
Consultant
Dayton Aerospace Inc.

Maj Gen George B. Harrison, USAF (Ret)
Director, Research Operations
Georgia Tech Research Institute

Dr. Mark A. Lorell
Senior Analyst
Rand Corporation, Santa Monica

Dr. Kenneth C. Pedersen
Vice President, Advanced Missile Systems
Raytheon Missile Systems Division

Dr. Harold W. Sorenson
Senior Vice President and General Manager
The MITRE Corporation

RADM Ronald C. Wilgenbusch, USN (Ret)
Consultant
RCW Consulting

Executive Officer: Capt Aaron T. Meadows, 5 CCG/CCE (ACC)
Technical Writer: Maj Stefan B. Dosedel, USAFA

People and Organization Panel

Mr. Jeffery B. Erickson, Chair
Manager, Crew Systems
The Boeing Company

Col Lynn Carroll, USAF (Ret)
Private Consultant

Col Roger Carter, USAF (Ret)
Program Manager, Advanced Information Systems
Lockheed Martin Corporation

Dr. Emily Howard
Technical Fellow
The Boeing Company

Dr. Miriam E. John
Vice President, California Division
Sandia National Laboratories

Maj Guy Jones, USAF (Ret)
Senior Systems Analyst
SenCom Corporation

Dr. Gary Klein
Chief Scientist and Chairman of the Board
Klein Associates Inc.

Prof. M. Elisabeth Paté-Cornell
Department Chair, Management Science and Engineering
Stanford University

Col Bruce Queen, USAF (Ret)
Director, Advanced Program Development Airborne Ground Surveillance & Battle Management Systems
Northrop Grumman

Lt Gen John B. Sams, Jr., USAF (Ret)
Director, C17 Field Services
The Boeing Company

Col Hugh Smith, USAF (Ret)
Manager, C^2 Operation
TRW, Systems and Information Technology Group

AFRL/HE Liaison: Dr. John Reising
Technical Advisor, Crew System Integration Division

Executive Officer: Maj Juan R. Berrios, ACC/INXX
Technical Writer: Capt John M. Feland, USAFA/DFEM

Vision and Bridging Concepts

Mrs. Natalie W. Crawford, Chair
Vice President and Director, Project AIR FORCE
RAND

Gen James P. McCarthy, USAF (Ret)
Olin Professor of National Security
United States Air Force Academy

Prof. Edward A. Feigenbaum
Stanford University

Lt Gen Everett H. Pratt, Jr., USAF, (Ret)
Private Consultant

Dr. Peter A. Swan
Chief Engineer and Vice President
SouthWest Analytic Network

Appendix D to Volume 2
Top Level Organizations Visited

7-8 March, Colorado Springs, CO, Acquisition Panel

Lockheed Martin, Colorado Springs**20-21 March, Hurlburt Field, FL, all panels**

C^2TIG, AC2ISRC, ESC, JointSTARS, C^2ISR Acq, C^2 Battlelab, JEFX 2000, SAF/AQI

22-24 March, Robins AFB, GA, People and Organization Panel

93rd Air Control Wing

27-28 March, Orlando, FL, People and Organization Panel

Air Force Agency for Modeling and Simulation

3-5 April, Hanscom, MA, Acquisition Panel

ESC

10-11 April, Langley AFB, VA, all panels

ACC Headquarters, AC2ISRC, ACC Network Operations Security Center

10-12 April, Hampton, VA, Interoperability Panel

JFCOM, JWC, JBC**13-14 April, Washington DC, People and Organization Panel**

Lockheed Martin, Boeing Information Systems, US Navy, DARPA

18-20 April, Washington DC, Acquisition Panel

SAF/AQ, DISA, DOE

25-27 April, Nellis AFB, NV, all panels

Air Warfare Center, Space Warfare Center, Red Flag, ESC Programs, Boeing IRAD, USAF Fighter Weapons School

28 April, Colorado Springs, CO, Acquisition Panel

Lockheed Martin

3-4 May, Hurlburt Field, FL, Concept and System Definition Panel

C^2TIG

8-12 May, Las Vegas, NV, Concept and System Definition Panel

Agile Combat Support Conference

8-12 May, Washington DC, Acquisition Panel

AFCEA sponsored Global Command and Control System course

16-17 May, Chantilly, VA, Interoperability, Technology, and Concept and System Definition Panels

NRO, DARPA

16-18 May, Washington DC, Acquisition Panel

DISA, USAF/XOC, SPAWAR, USAF/XOJ, SAF/AQI, USAF/XOR, USAF/SC, and USAF/XPP

18 May, Washington DC, Concept and System Definition Panel

DARPA

18 May, Crystal City, VA, Interoperability Panel

Lockheed Martin, OASD/C^3I, JSF Program Office

23-25 May, Langley AFB, VA, Technology Panel

Fusion Briefings

30 May-1 Jun, Wright-Patterson AFB, OH, People and Organization Panel

AFRL Human Effectiveness Directorate

7-9 June, Davis Monthan AFB, AZ, Concept and System Definition Panel

12 June, Rome, NY, People and Organization, Interoperability, Technology, and Concept and System Definition Panels

AFRL Information Directorate

13-14 June, Hanscom AFB, MA, all panels

ESC

21 June, Washington DC, Interoperability Panel

HQ US Army/DISC4

21-22 June, Langley, AFB, VA, Technology Panel

ISR Briefings

26-27 June, Interoperability and Technology Panels

SPAWAR System Center, SPAWAR Acquisition, SWC

26-27 June, Washington DC, Acquisition Panel

DISA, Ballistic Missile Defense Organization, SPAWAR, and Advance Information Technology Service Joint Program Office

27-30 June, Seattle, WA, People and Organization and Concept and System Definition Panels

Boeing Phantom Works, Space and Communication

30 June, Ft Monmouth, NJ, Interoperability Panel

Army PEO/C3S

10-21 July, San Jose, CA, all panels

SAB Summer Session

10-21 July, San Jose, CA, Technology Panel

Oracle Corporation, Sun Microsystems, JavaSoft, TBMCS Briefing

17 July, San Diego, CA, Interoperability, People and Organization, and Concept and System Definition Panels

US Navy Command Ship Coronado

7 August, Wright-Patterson AFB, OH, Acquisition Panel

AFMC HQ, ESC, ASC

(This Page Intentionally Left Blank)

Continuation of Appendices to Chapter 4
Report of the Technologies Panel

(This Page Intentionally Left Blank)

Appendix 4D
Information Assurance

The steps taken to protect our information collection, transfer, and storage, which constitute information assurance, can be decomposed into the following areas:

A. Protection of our sources of Intelligence - Information used in military operations is collected from many sources, including passive and active sensors. The sensors usually ride on platforms, such as aircraft or satellites, controlled or directed from various operations centers. The provide intelligence preparation of the battlefield, intelligence during operations, and operational effectiveness data. Sensor and platform protection are essential needs for information assurance.

Finally, much of the information driving decisions in a theater war, particularly a limited conflict is produced by human agents. Some of these are insiders in the enemy society or force, others are U. S. collectors, such as Special Forces teams operating in enemy territory. In either case, it is incumbent on U. S. Forces to protect these sources. In some cases protection can be in the form of distracting or confusing information, and in other cases actual physical force may be necessary. The Air Force should develop basic principles for both forms of protection, at least where information operations or deployment of air or space power is concerned. C^2 systems must be able to take into account planning operations to protect our intelligence sources.

B. Protection of the links from intelligence sources into the C^2 system - Communication links to sensors are vital parts of an information collection system. Control information is transmitted to a sensor, be it aircraft, ground force, human agent, or satellite, and information is transmitted from the sensor to the sensor data user. Frequently, but not always, information is transmitted by wireless link. Communication channels, wireless, fiber, or other, must be protected. There must be methods of detecting and recognizing jamming of either the command or response links and responding effectively. Robustness of connectivity (such as anti-jam capability), multiple independent transmission paths, and ability to operate with degraded connectivity are the most effective approaches. Corruption of data as the result of enemy jamming or damaging of repeater amplifiers or transmission systems is rather easy to detect even if repair is difficult. Error detection and correction methods can help to keep track of these errors. Monitoring of transmission error rate is a fundamental task for a communication system.

Intercept of information being transmitted is a threat that can be treated in several ways. The classical method is through encryption, and much development of encryption methods, particularly public key methods, is underway in the civil, commercial, community. Quantum encryption techniques that provide protection through fundamental physical principles are being developed in government and university laboratories. This method guards against undetected replacement of data. These methods should be studied by the Air Force.

Spread Spectrum communications can be used to make it difficult, or impossible to detect or intercept the signal. This has been used with great benefit for agent-in-place and Special Forces communication systems.

C. Protection of the links within the C^2 system's network(s) – All C^2 systems require connectivity between their component parts. Shared data-bases must be connected, and user

workstations as well. Most of these links are carried terrestrially, and increasingly are carried tunneled within publicly accessible connectivity such as the Public Switched Telephone Network (PSTN) or Internet trunks. These links must be protected from Denial of Service (DoS) attacks and intrusion. While NSA certified cryptos provide excellent intrusion protection and Transmission Security (Transec), other techniques such as link robustness, multiple redundant link paths, and ability to operate with degraded connectivity are essential to operating during a DoS attack.

D. Protection of the data that resides within the system – Modern C^2 systems contain or access large data libraries and maintain a data-base containing a representation of the battlespace. Techniques to detect and correct data corruption, caused by random errors or deliberate intrusion, are essential to information assurance in this area. Destruction of information is usually easy to detect. Detection of replacement and corruption is more difficult. The integrity of stored data is primarily maintained by the storage device itself. Devices may be susceptible to natural or artificial electromagnetic signals. Critical storage devices should be equipped with detectors that will warn the user if the device experiences electric or magnetic fields that could disrupt data stored in the device.

The most likely way in which data can be disrupted is through access and replacement by friendly users. A record of access and, particularly, modification of data by authorized users and applications should be kept. The record can be reviewed periodically to determine if dangerous corruption may have occurred.

Retrieval errors are similar to transmission errors, and the considerations for transmission errors apply. In addition, retrieved information is usually directed to a predetermined location. Misdirection is possible as the result of enemy action, human error, or computer equipment failure or program bugs. Misdirection is easy to detect, but real-time analysis of the reason for misdirection will be very useful in eliminating the problem.

Computer program bugs do not always appear during simulation, exercise, or beta testing of applications. All of those methods provide valuable, but somewhat idealized situations. Data and application interactions that are unanticipated may cause conflicts and errors that can even be catastrophic. Applications can be analyzed and tested for the most common errors. Records of errors and their resolutions should be kept. Detection and repair methods can eventually be included in compilers or, even, in the applications themselves.

The threat from knowledgeable and treacherous insiders can never be completely eliminated. Constant vigilance must be maintained. An unlikely, but potentially catastrophic, danger is from malicious compiler and tool designers. As the Air Force becomes more dependent on commercial products, some, or many, of these products will be manufactured abroad.

The operating system is the heart of any computer. Access to all the capabilities of the computer and many of those of the network can be gained through unrestricted access to the operating system.

Vulnerability to penetration can be through compromise of passwords, classical “hacking” methods, or trap doors. Existing and new applications should be scanned to make sure that access violations will not occur.

E. Protection of the links the system uses to command external resources – The links the system uses to command action, either of battle resources or of intelligence collectors, are subject to the same sort of attack as the links from our sensors. They may be protected using the same techniques.

Technologies being developed to provide information assurance are summarized in the following tables.

Table 4D-1. *Secure Networking*

Problem	***Technology***	***Description***
Internet routing infrastructure subject to denial of service attacks	Secure OSPF (open shortest path first) routing protocol Nimrod routing security	Authentication added to routing
Internet naming and addressing infrastructure is vulnerable to denial of service attacks	Internet Protocol (IP) version 6 (IPv6, also known as IPsec) prototype Secure Domain Name Service (DNS) protocol	IPv6 encrypts IP packets Secure DNS adds authentication and authorization to DNS
Network security services are not easily integrated into applications	Cryptographic application programming interfaces (CAPI) Simple public key interface (SPKI) Key mgmt interfaces	These interfaces give programmers standard ways of adding security functionality to software
Network security services are not interoperable	IPsec key agreement protocol Secure Mobile IP	Multi-layer security negotiation protocol Mobile IP security protocol preserves user identity for nomadic users traveling across different networks
Encrypting group communication and managing membership changes not scalable to large groups	Secure fault-tolerant group communication	Scalable algorithms for key management and membership revocation, and language for specifying group communication policies
Traditional operating system security inappropriate for modern networked environments with complex policies	Domain-Type Enforcement (DTE)	Fine-grain access control and an associated policy “compiler”
Adequate security available only in special-purpose OS’s with tiny market	Fluke operating system	Security is being integrated into commercially viable next-generation OS’s
Distributed systems meeting more than one critical property are beyond the state of the art	Horus distributed computing system	Group communications system supporting secure, real-time, fault-tolerance
Rigid security and firewalls inhibit tightly coupled cross-domain applications and establishment of temporary security associations	Adage authorization server Sigma security middleware	A distributed authorization server and policy language Propagation of access control information across enclave boundaries

Table 4D-2. *Detection and Tolerance*

Problem	***Technology***	***Description***
Current intrusion detection techniques are limited to detecting a small set of well-known events	Emerald intrusion detection system	Detects unknown attack types on networks
Current detection techniques do not scale, and do not support automated response	– GRIDS intrusion detection system – Intrusion Detection and Isolation Protocol (IDIP)	– Allows attacks to be specified as a graph across a network, thus allowing detection of larger-scale attacks – Allows coordinated detection and automated response
Current technology does not support incident response, which is costly labor-intensive process	DERBI (Diagnosis, Explanation and Recovery from computer Break-Ins)	Tool to analyze a system for indicators of a possible intrusion. DERBI explains to the system administrator what it found, what it likely means, and how to recover.
Lack of standards impedes adoption of even current technology	Common Intrusion Detection Framework (CIDF)	Establishes standard interfaces for event generators (sensors) and analysis engines (detectors)
Current intrusion detection detects only attacks on isolated machines rather than on the network infrastructure	JiNao intrusion detection system	Detects intruders in network routers, switches, and network management channels. Integrated with network management and has reconfiguration capabilities
Multicast group communication protocols vulnerable to malicious participants	Secure Group and Secure Ring protocols	Group communication protocols that can prevent a malicious processor from disrupting the correct delivery of messages and from denial of service attacks
Common programming errors leave most systems vulnerable to buffer overflow attacks, the most common type of attack on the Internet	Stackguard compiler	Programs compiled with StackGuard are not vulnerable to buffer overflow attacks. No source code changes are required, and executables are binary-compatible with existing operating systems and libraries

Table 4D-3. *Wrappers*

Problem	***Technology***	***Description***
Commercial products introduce unreliability and security risks	Generic Security Wrappers	Wrapper technology to augment legacy & COTS components with security functionality. Includes a wrapper specification language and a kernel-resident wrapper system. It intercepts system calls to control privileged and non-privileged programs. Demonstrations include control of administrative privileges, access control, and encryption
Integrators cannot assemble components and wrappers into a trustworthy whole	Composable Replaceable Security Modules	A tool to build security into systems by assembling security functions from a library of reusable, plugable security modules, with standard functionality and interfaces
Evaluation of vulnerability/resistance of a product or system	Vulnerability Assessment Tool	White-box security evaluation tool locates vulnerable points in source code, using realistic attack models and taxonomies of known security flaws

(This Page Intentionally Left Blank)

Appendix 4E
Revolution In Battlefield Awareness Of
Advanced Ground Moving Target Radar

There is a significant technical advancement in Ground Moving Target Indication (GMTI) radar for tactical and strategic Intelligence, Surveillance and Reconnaissance (ISR) that will provide a major leap ahead in the Dominant Battlespace Awareness for the battle commander required to satisfy Joint Vision 2010.

Rather than just slowly updated moving dots, advanced GMTI radar systems will be able to provide high update moving target detection and individual target features thus providing much higher quality information about the nature and dynamics of thousands of moving targets over large areas. This information will include accurate geo-registered target location; velocity of the target; simultaneous feature measurements of individual moving targets such as size, high range resolution (HRR) profile (1D), and synthetic aperture radar (SAR) and Inverse SAR (ISAR) which produces 2D images of both fixed and moving targets. This enhanced information thus provides a dynamic picture of vehicle characteristics, speed, where they are coming from and going to, and the number of vehicles moving in specified areas. The vehicle features or attributes coupled with high update track data provides significant information concerning type of military unit convoy characteristics such as: number, type and mix of vehicles; vehicle traffic and passing activities as a function of road type; mix of civilian vs. military traffic; indications of roadblocks, bridges or other traffic constrictions; associated helicopter movement, congregation of vehicles at areas that can be command posts or logistics/refueling areas; traffic sources such as known military installations; and traffic sinks or destinations that can be associated with military units etc.

GMTI radar high update detections coupled with high range resolution vehicle feature information is significantly different from imagery. Finding stationary enemy targets in large areas with high resolution imagery can overwhelm the exploitation task (20 to 200 Mbits/sec) and requires large numbers of highly trained human image analysts to exploit. Automatic or computer aided target recognition of SAR imagery can help cue the human analyst but is not yet an automatic process and will always require large processors. On the other hand, advanced dynamic GMTI radar detections and their associated high resolution target feature information is a fairly low data rate information stream (100’s Kbits/s to a few Mbits/s dependent on vehicle count) that can be processed automatically. If processed into tracks, with associated target recognition tags, this data becomes at least an order of magnitude lower than even the raw GMTI data. Not only is GMTI track data easier to analyze, the tracks lend themselves to further automated track analyses such as:

- Multiple hypothesis tracking (position, time, velocity and direction)
- Counting of number of vehicles as a function of areas or boundaries
- Source determination of target vehicles & their destination including traveled road/path
- History of movement over time
- Target evidence and recognition feature accrual and comparison over time

This automatic analysis of moving target information is significantly easier and faster than that required for the analysis of complex imagery by either human or automatic image recognition.

As stated before this is a common experience of every hunter or fighter pilot which can easily spot moving game or aircraft but has difficulty seeing stationary targets even when close. Dynamic GMTI information and tracks are inherently time/geo-registered, provides immediate indication and warning information and correlates well with imagery and signals intelligence data thus providing a Common Operating Picture (COP) of the battlefield. GMTI tracks can come from simultaneous multiple radar sources that can be automatically fused together by new techniques in computerized multiple hypothesis processes.

The new advanced GMTI radars will provide update rates that are dynamically adjustable depending on target dynamics (velocity, acceleration, on-off road, intersecting roads), range, terrain visibility, warfighter area of interest, location accuracy required and other target track filter needs. The enemy has a very difficult task to hide, conceal or confuse large numbers of vehicles dynamically moving in the open. GMTI by its very nature provides a truth picture of enemy movement and intention particularly if the enemy intent is to engage in battle.

Not too long ago, military commanders thought of GMTI surveillance radar of the ground as a snap shot picture of what was moving at a point in time. The venerable Army Mohawk SLAR was an example of that type of picture which was hardly dynamic in nature but gave a picture of the number of moving vehicles at a point in time. In the early 1980's, technology progressed to the point where passive phased array GMTI radars could provide a wide area picture of moving targets every 30 to 60 seconds providing a more dynamic update of target movement even if it was only moving dots or blobs.

These current GMTI radars do a good job of detecting mass enemy movements and providing a degree of battlefield awareness. But, the information lacks target recognition features and is therefore a moving history of dots or blobs with insufficient update rate for significant tracking over large areas. The data can be registered on terrain maps or images with a background of apriori terrain and road database information. A compressed time history of the data shows a human analyst enemy target movement portrayed as a strobe or smoke trail on the display that allows human operators to discern movement and direction and learn to recognize characteristics of enemy motion. The radars are not able to provide continuous GMTI because of insufficient power-aperture, the need for interruptions to collect SAR imagery (15-45 sec depending on range and resolution) as well as blanks in data due to aircraft orbit turns (lasting 3-5 min). Because of these gaps, the lack of target feature measurements and their slow update rates, these radars are limited in their ability to provide battlefield intelligence, reconnaissance, battle damage assessment, or precise moving target location capability. They are, however, very useful as indications and warning, battle management and command and control systems for providing battle commanders information on enemy motion and the timing of events as well as providing coarse information for target – weapon pairing and subsequent target reacquisition by strike forces.

Radar Technology Advances

Technical GMTI advances have occurred in the past few years that significantly changes the capability to provide even more useful dynamic battlefield information. Some of the major technical advances are:

- Active Electronic Scanned Arrays (AESA) (1D or 2D steering) use distributed low cost solid state modules to feed each radiating element:

- The resulting AESA is a highly modular and scaleable approach that will allow significantly lower manufacturing cost over that of older tube transmitter designs
- Production MMIC Transmit / Receive (T/R) X band (8-12 GHz) modules typically come in 1, 5 or 10 watt powers and are projected to cost less than $500 per radiator site.
- T/R modules in close physical proximity to the radiating elements have both high efficiency and much lower losses thus providing high effective radiated powers.
- Planar multi-layer printed circuit board manifolds distribute low voltage DC prime power, low level RF signals and digital control signals to the active T/R modules.
- Compact, distributed, high power solid state low voltage DC power supplies feed power to the T/R modules.
- The T/R modules and radiating elements have multi-giga Hertz tuning ranges and very wide band instantaneous bandwidth capable of ultra high resolution waveforms.
- The solid state T/R modules have very high reliability and graceful degradation that can approach the life of the airframe carrying it.
- The continuing march of faster and faster embedded digital signal processors currently allows greater than 100 Giga-Operation/second per cubic foot, with the promise of Tera-Ops/cubic foot in the near future
- Wide band frequency hop/chirp exciter/receivers with capability for greater than 1 GHz instantaneous bandwidth will provide high resolution modes from 0.1 to 1 meters and tuning ranges in excess of multiple GigaHertz.
- Active aperture radars allow simultaneous/interleaved pulse to pulse modes (GMTI, High Range Resolution (HRR) and SAR Imaging) with manageable performance degradation from operating in these simultaneous modes.
- Advanced processing schemes for multi-beam Space Time Adaptive Processing (STAP) allows improved cancellation of moving ground clutter as well as adaptive spatial nulling of jammer and interference signals.
- Automatic moving target tracking of large number of targets using Multiple Hypothesis Tracking (MHT) and kinetic and Kalman filter algorithms. Such trackers use feature evidence accumulation and pruning to sort out targets from false alarms and confusing dense adjacent traffic even in the presence of road intersections and drop outs.
- Automatic moving target feature recognition using High Range Resolution (HRR) one dimensional range profiles of large numbers of targets (measured in 0.1 to 0.2 secs/measurement) as well as 2D imaging using both inverse SAR techniques (1-3 secs) as well as Moving Target Imaging (MTIm) SAR (10-30 secs) that is able to image moving targets. The speed of the HRR mode works very well to aid automatic trackers to provide feature evidence to rapidly recover track drop outs in dense traffic or confusing road situations. Initial tests of multi-look HRR at 1ft resolution has achieved target recognition in the 85-95% range. HRR will also provides target fingerprinting to aid track maintenance.

Summary of Modern Active ESA GMTI/SAR Radar

The new advanced airborne GMTI radar can provide a significant source of tactical, theater and even strategic intelligence about dynamic enemy force movement thus providing revolutionary performance in battlefield indications and warning, synoptic battlespace awareness, target/weapon pairing information and real time wide area battle damage assessment unlike any in the past:

- High update rate track of 1000's of individual vehicles over wide areas and at significant ranges

- Target recognition that turns moving dots into recognized target entities
- Automatic real time signal and data processing
- Significant intelligence about enemy forces such as automatic sentinels around areas, vehicle counts, sources/sink detection, convoy and group detection and tracking data and history of movements.
- Interleaved, simultaneous GMTI, SAR and target recognition modes
- Ultra high resolution SAR spot images with 2-3 times the resolution of current fielded systems

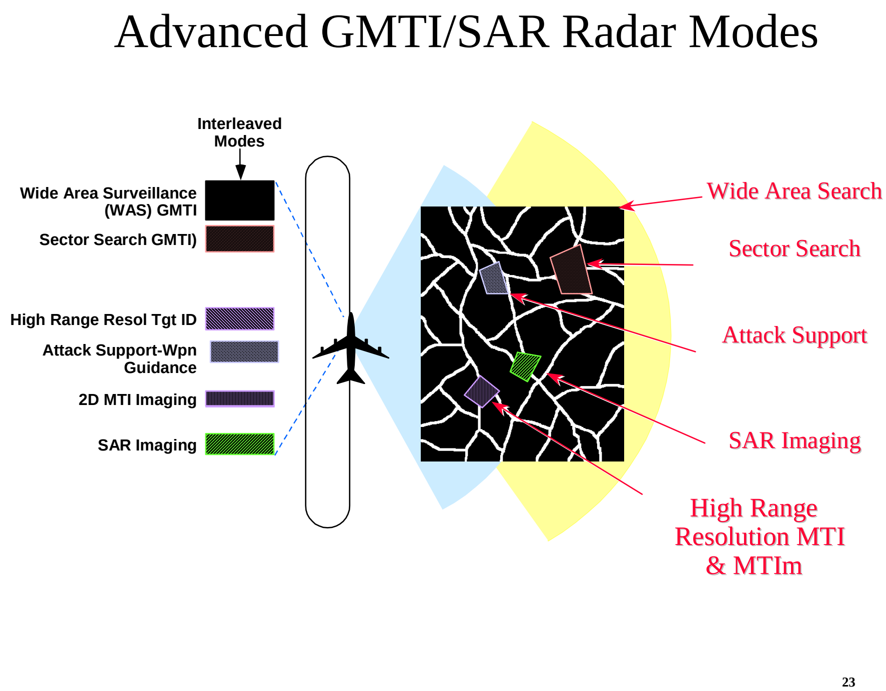


Figure 4E-1. *Advanced GMTI/SAR Radar Modes*

Continuation of Appendices to Chapter 6
Report of the Acquisition and Program Management Panel

(This Page Intentionally Left Blank)

Appendix 6C
The Current Air Force Acquisition Process for C^2 Systems: A Case Study of TBMCS

Summary

The Theater Battle Management Core Systems Program (TBMCS) is the current Air Force flagship program for automating and integrating the planning and execution of the theater air war. This report provides a detailed developmental case history of TBMCS from the late 1980s through June 2000. This case study was commissioned by the Acquisition Panel of the US Air Force Scientific Advisory Board (SAB) 2000 Summer Study entitled "Air Force Command & Control—the Path Ahead." It is intended to illustrate how the Air Force developed and procured its most important tactical command and control systems in the 1990s. The purpose of this case study is to help identify areas where the Air Force can improve its acquisition strategies in the future for tactical command and control systems. The account presented here is based almost entirely on interviews with key Air Force and industry participants in the TBMCS program, as well as on the extensive historical written documentation of the program made available to the author by the TBMCS Program Office located at the Electronic Systems Center, Hanscom Air Force Base.

The five core functions of TBMCS can be defined as (1) intelligence collection and evaluation, (2) planning, (3) generating and distributing the Air Tasking Order (ATO),[53] (4) unit level scheduling of missions; and (5) monitoring execution of the ATO. TBMCS is intended to link these intelligence, planning, and operations functions through the integration of several legacy systems (or their equivalent functional capabilities), the most important of which are the Combat Intelligence System (CIS), the Contingency Theater Automated Planning System (CTAPS), and the Wing Command and Control System (WCCS). In addition, TBMCS migrates these key theater air warfare applications to the Defense Information Infrastructure Common Operating Environment (DII COE).[54]

TBMCS has experienced a troubled and controversial history since its formal launch in late 1995, when Loral Command and Control Systems (LCCS, now Lockheed Martin Mission Systems [LMMS] of Colorado Springs) won a six-year competitive cost plus award fee (CPAF) contract valued around $180 million. The program has suffered from significant schedule slippage, some cost growth, and major performance short falls.[55] The original concept

---

[53] The ATO is a method used to task and disseminate to components, subordinate units, and command and control agencies projected sorties/capabilities/forces to targets and specific missions. Normally it provides specific instructions to include call signs, targets, controlling agencies, etc., as well as general instructions. (See the Defense Technical Information Center (DTIC) DoD Dictionary of Military Terms).

[54] The DII COE is DoD's common software infrastructure, architecture, and set of guidelines and standards, which will be used for all military C4I systems, such as the Global Command and Control System (GCCS).

[55] The original contract value to the prime contractor was $35 million (excluding fee, zero base fee), with options that were eventually exercised amounting to $109 million, resulting in a total of $144 million. Award fees and miscellaneous changes raised this to $179 million. A category labeled "evolutionary Requirements (technical task

envisioned the fielding of three progressively more capable software releases, with the final V 3.0 release available in 2001. Early in the program, release of Version 1.0 was planned for March 1998. Instead, as of June 2000, the program still had not been able to successfully complete and field Version 1.0. In addition, the Version 1.01 represented a significant down-scoping in the capabilities envisioned earlier for the first release.[56] As a result, many observers have viewed TBMCS as a seriously flawed program with regard to its development process and other factors, at least in the early phases.

As of mid 2000, however, the program generally appeared to be on track. A detailed plan for the fielding and future upgrading of the system has been developed.[57] Nonetheless, its many problems make it worth examining carefully for "lessons learned" for future Air Force approaches for tactical C^2 systems acquisition. It is a story that the Air Force should avoid repeating.

Based on this detailed case study, we conclude that the problems experienced on TBMCS were caused primarily by the following factors:

Lack of sufficiently detailed concept of operations (CONOPS), concept of employment (CONEMPS), system architecture, and operational requirements. TBMCS was launched with a strong visionary high-level CONOPS and system architecture. However, these lacked the detail necessary to provide appropriate guidance to the Air Force and contractor Program Managers (PMs) for development of the system. No formal Operational Requirements Document (ORD) was ever produced.[58] The problem was compounded by the lack of consensus among the user communities over CONOPS and operational requirements, and by continual change and evolution. The constant refrain of the contractor remained throughout the program: "Will the real user please stand up?"[59]

Lack of consistent, strong advocacy leadership on the highest levels of the Air Force, and at the SPO and contractor levels, particularly during crucial points during the program. Initially TBMCS had a few strong advocates on the highest levels of the Air Force. This is particularly true during the very early phases of the program when John Gilligan was the Program Executive Officer (PEO). Yet at one key point during the development phase, an Air Force Major, far down in the SPO hierarchy, acted as the de facto PM for at least six months during a crucial development period. The program lacked clear lines of authority and strong leadership both on the government side and the contractor side. Perhaps most important, there was no single powerful focal point of responsibility, advocacy, and oversight for the program. This was particularly true in the area of requirements development.

Inappropriate application of current acquisition reform (AR) doctrines of transferring greater system definition responsibility to the contractor. Partly by default, and partly

---

descriptions)" added an additional $161 million, for a total contract value in mid 2000 of $327 million. Mr. Steven Kent, ESC, provided this information.

[56] However, TBMCS Version 1.01 also includes other capabilities not envisioned in 1995

[57] TBMCS passed its Field Demonstration Test in June 2000. A Multi-Service Operational Test & Evaluation took place in late July.

[58] CTAPS and WCCS did have formal System Operational Requirements Documents.

[59] Interview by author with Reese Delorey, TBMCS Lockheed Program Manager, 15 April 2000.

because of DoD acquisition reform doctrine, program officials granted the prime contractor significant control over the development of the system operational architecture, configuration, and even CONEMPS. Especially in the early phases of the program, the contractor senior management lacked the operational knowledge, technical skills, and initiative to meet this challenge effectively without greater guidance from the Air Force. Clear guidance was not forthcoming, because no consensus existed in the Air Force on these issues.

Use of a "big bang" development approach instead of a spiral approach, which delayed fielding, and resulted in operator pressure to divert resources to fixing legacy systems.[60] The TBMCS contract called for the development and fielding of three major software releases over a six year period. The user community lobbied hard for a much quicker fielding of initial capabilities. This led to the decision to divert significant resources to fixing existing fielded systems (CTAPS, CIS, WCCS). This effort proved far more difficult than anticipated, leading to significant delays in the TBMCS program, because the fielded legacy systems were seriously flawed. In theory, a spiral development approach could have led to a much earlier fielding of initial capabilities, thus reducing the pressures to divert resources to fixing legacy systems.

Insufficient "jointness" in the original program planning vision. Failure to include sufficient joint vision in initial program planning contributed to the unanticipated need to rehost CTAPS to Sun Solaris and HP Unix servers for Navy shipboard operations. This was identified as a major unplanned diversion of resources. In general, Navy requirements and needs were not sufficiently recognized in the early phases of the program. The scale of the Air Support Operations Center (ASOC) upgrade program effort for the Army Corps level was also underestimated.

Underestimation by both the government and prime contractor of the technical difficulty of integrating legacy systems. Multiple contractors had developed the legacy software modules which would go into TBMCS, usually in conjunction with a specific government laboratory and a specific user command. Thus the pieces that would make up TBMCS had no uniformity in architecture, computer language, etc. Little formal documentation existed, resulting in difficulties in transferring the necessary legacy information to Lockheed. This problem was exacerbated by third party "associate" contractors which had no formal contractual relationship with Lockheed. Finally, some particularly troublesome modules, such as FLEX, were developed by labs as technology demonstrations, and were not appropriate for fielding. In the case of FLEX, neither the SPO nor Lockheed had direct control over development. Finally, virtually all the legacy modules were more immature technically than originally anticipated. One TBMCS

---

[60] Spiral Development is a developmental process commonly used in the commercial software world for incremental development and rapid fielding of new capabilities. It is based on iterative, short development cycles that focus on risk areas, and which integrate users, developers, acquirers, and testers. Air Force Instruction 63-123 *Evolutionary Acquisition for C2 Systems*, 1 June 2000, provides a guide for mandatory use of the spiral development process in Air Force C2 development programs. Some authorities believe this document does not adequately describe the process of spiral development as used in the commercial world. For one discussion of the concept, and the problems of implementing it in military C2 acquisition programs, see the briefing *WG4 Institutional Challenges*, prepared by members of the Spiral Workshop, February 2000, sponsored by the Carnegie Mellon Software Engineering Institute, and the Center for Software Engineering, University of Southern California.

Program Manager summed up this issue by noting: "the biggest failure of TBMCS has been setting unrealistic levels of expectations."[61]

Inadequate process for controlling and screening requirements and capabilities development and additions. The user community continued to develop independently new modules and capabilities that were progressively folded into the program. No process existed to assess, prioritize, and filter these, leading to much added integration work for the prime contractor. Little discipline was exercised over requirements growth and change by either the government or the prime contractor, since no clear baseline configuration was ever established early in the program.

Lack of an appropriate strategy for testing and fielding the system. The program did not develop a consensus on a unified testing concept and approach, nor on test metrics for judging success. A lack of a unified and detailed CONOPS and CONEMPS resulted in the lack of a standard use pattern by users. Different testers, with different use patterns, and using different test metrics, conducted the various operational and fielding tests, producing widely varying results.

The following section, a case study of the development of TBMCS, has not been cleared for public release. In the event you have a need to obtain this information, please contact the Executive Director of the U.S. Air Force Scientific Advisory Board at (703)-697-4811.

[61] Note to author from Carl Steiling, 18 August 2000.

Acronyms

AADC	Area Air Defense Commander
ACC	US Air Force Air Combat Command
ACC/DR	Deputy Chief of Staff for Requirements, Air Combat Command
ACPT	Air Campaign Planning Tool
AFMC	Air Force Materiel Command
AFMSS	Air Force Mission Support System
AFOTEC	Air Force Operational Test and Evaluation Center
AFSC	Air Force Systems Command
ALC	Air Logistics Center
AMC	US Air Force Air Mobility Command
AOC	Air Operations Center
APS	Advanced Planning System
AR	Acquisition reform
ASOC	Air Support Operations Center
ASP	Acquisition Strategy Panel
ATO	Air Tasking Order
BSD	Battlefield Situation Display
C^2IPS	Command and Control Information Processing System
C3	Command, control and communication programs
CAF C^2 SPO	Combat Air Forces Command and Control System Program Office
CAFMS	Computerized Assisted Force Management System
CAOC	Combined Air Operations Center
CCB	Configuration Control Board
CIS	Combat Intelligence System
CMM	Capability Maturity Level
COP	Common operational picture
COTS	Commercial-Off-the-Shelf
CPAF	Cost Plus Award Fee
CTAPS	Contingency Theater Automated Planning System
CTIS	Command Tactical Information System
DE	Domain Engineering
DIA	Defense Intelligence Agency
DII COE	Defense Information Infrastructure Common Operating Environment
DISA	Defense Information Systems Agency
DR	Directorate of Requirements
DRs	Deficiency Reports
ECP	Engineering Change Proposal
EOB	Enemy order of battle
ESC	Electronic Systems Center
Evms	Earned Value Management System
Fdt&E	Final Development Test and Evaluation
FFRDC	Federally funded research and development center
FLEX	Force Level Execution
FYDP	Five-Year Defense Plan
GCCS	Global Command and Control System
GOSG	General Officer Steering Group
GTACS	Ground Theater Air Control System
GTN	Global Transportation Network

ICM	Intelligence Correlation Module
IDE	In-process Design Evaluation
INEL	Idaho National Engineering Laboratories
INRI	Inter-National Research Institute Inc.
JAT	Joint Acceptance Test
JFACC	Joint Force Air Component Commander
JFAT	Joint Fielding Acceptance Test
JMCIS	Joint Maritime Command Information System
KLFs	Key legacy functions
LCCS	Loral Command and Control Systems
LMMS	Lockheed Martin Mission Systems
MAJCOMS	Major Commands
MAOC	Modular Air Operations Center
MCFs	Mission critical functions
MENS	Mission Needs Statements
MIDB	Military Integrated Data Base
MOT&E	Multi-Service Operational Test & Evaluation
NAFs	Numbered Air Forces
O&M	Operations and Maintenance
OB	Order of Battle
ORD	Operational Requirements Document
OTAS	Operational Test Assessments
PACAF	Pacific Air Forces
PE	Program Element
PEO	Program Executive Officer
PM	Program Manager
PMR	Performance Metrics Reporting
Pri	Priority
R/SAOC	Regional/Sector Air Operations Center Modernization Program
RAAP	Rapid Application of Air Power
RFP	Request for Proposal
SAB	US Air Force Scientific Advisory Board
SAIC	Science Applications International Corporation
SLOCs	Single Lines of Code
SON	Statement of Need
SOR	System Operational Requirements Documents
SPAWAR	US Navy Space and Naval Warfare Systems Command
SSEB	Source Selection Evaluation Board
STRATCOM	Strategic Command
SWPS	Strategic Warfare Planning System
T/DRs	Test Discrepancy Reports
TAC	Tactical Air Command
TAP	THEATER AIR PLANNING
TBM	Theater Battle Management
TBMCS	Theater Battle Management Core Systems Program
TSPR	Total System Performance Responsibility
TTDs	Technical Task Descriptions
WCCS	Wing Command and Control System

GCCS Integration Process

<u>Microsoft Model</u>

Configuration Managed
Operating System (Windows 2000)

Tightly Integrated
Killer Applications (Power Point)
Partner Developed
Applications (Quicken)

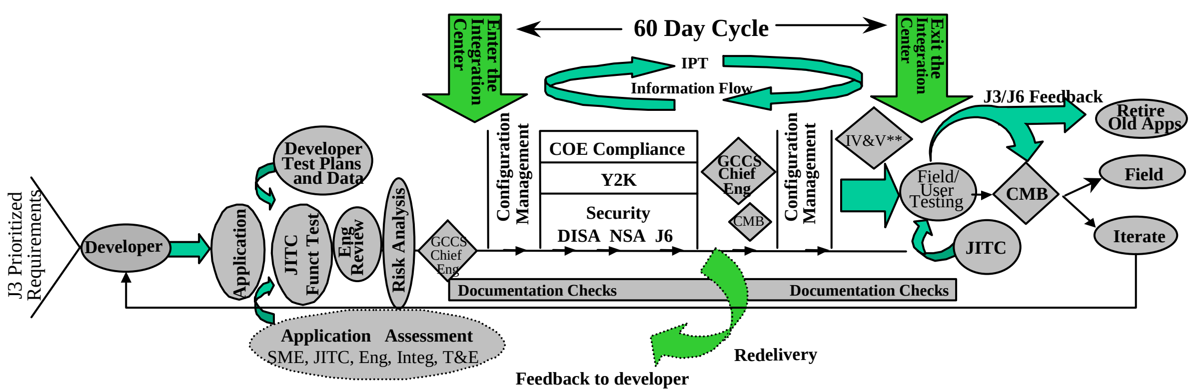
- MARKET SHARE

<u>GCCS Model</u>

Configuration Managed
Operating System (COE Kernel)

Tightly Integrated
Killer Applications (COP)
Partner Developed
Applications (I3*, METOC)

- INTEROPERABILITY -



* I3 - Integrated Imagery and Intelligence

** IV&V- Independent Verification and Validation

(This Page Intentionally Left Blank)

Appendix 6E
GCCS Mission Applications Schedules

Mission Applications Schedule

			1998	1999	2000												2001											
Community		Executive Agent			J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	Office Automation																											
OPS	NetMeeting	DISA/NCI	▲ T																									
OPS	PCXware	DISA/NCI	▲ T																									
OPS	Seagate Backup	DISA/COTS	▲ T					△	S																			
OPS	Office97 (Office 2000)	DISA/MS	▲ T					△	S			△																
OPS	Defense Message System Automated Message Handling System (DMS AMHS) Message Manager (MM)	DISA						△																				
OPS	Remote Dial (AT&T STU III)	DISA/AT&T		▲ T				△	S																			
OPS	Secret Agent	DISA/AT&T	▲ T					△	S																			
OPS	Front Page	DISA/MS	▲ T					△	S																			
OPS	Defense Message System Automated Message Handling System (DMS AMHS) Outlook-T	DISA							△	T																		
	Force Planning																											
OPS	JOPES Editing Tool (JET)	DISA	▲	▲ ▲		▲				△					△	J2K												
OPS	Rapid Query Tool (RQT)	DISA	▲	▲						△					△	J2K												
INTEL	Global Reconnaissance Information System Web Interface (GRISWI)	DISA						△																				
OPS	Common Operational Modeling, Planning and Simulation Strategy (COMPASS)	JPO	▲	▲				△																				
LOG	Joint Forces Requirements Generator (JFRGII)	USMC							△																			
OPS	Nickname, Code Word and Exercise Term (NICKA)	DISA								△																		
OPS	Force Module Editor (FMEDIT)	JPO											△															
OPS	Theater Analysis and Replanning Graphical Execution Toolkit (TARGET)	JPO											△															
OPS	Adaptive Courses of Action (ACOA)	JPO								△							△						△				△	
OPS	Nuclear Weapons Contingency Operational Module Server (NWCOMS)	DTRA															△											

V - Version S - GCCS Secret T - GCCS Top Secret * - Limited Distribution △ - Current Projected Fielding ▲ - Actual Fielding

Mission Applications Schedule (continued)

			1998	1999	2000												2001											
					J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Community		Executive Agent																										
	Readiness Assessment																											
OPS	Global Status of Resources and Training System (GSORTS)-Input Tool	DISA		▲																								
OPS	Global Status of Resources and Training System (GSORTS)-Output Tool	DISA		▲												△	V4.0											
OPS	Automated Joint Monthly Readiness Report (AJMRR)	JPO														△												
	Situational Awareness																											
USAF	Air Force Option 4 (AFO4)	USAF	▲																									
LOG	Medical Analysis Tool (MAT)	Army		▲																								
LOG	Global Combat Support System (GCSS) COP-CSE *	DISA		▲					△																			
Common	METOC System (JMS)/METOC Imagery System (MIS)	USN		▲																								
OPS	Information Dissemination Management (IDM)	JPO						△	R2					△	R3.1													
OPS	COP Embedded Training	DISA					▲																					
Common	Meteorological and Oceanographic Tactical Forecast System (METOC TFS)	USAF					▲																					
INTEL	Integrated Intelligence and Imagery (I3)	USN							△																			
OPS	Joint Defense Planner (JDP)	USAF									△																	

V - Version   S - GCCS Secret   T - GCCS Top Secret   * - Limited Distribution   △ - Current Projected Fielding   ▲ - Actual Fielding

Appendix 6F
GCCS Mission Applications Abstracts

Fielded

- Air Force Option 4
- COMPASS NT
- COP Embedded Training
- Front Page (T)(S)
- GCSS COP-CSE
- GRISWI
- GSORTS (E) Input/Output
- JET (T)(S)
- MAT
- METOC JMS/MIS
- METOC TFS
- NetMeeting (T)
- Office97 (T)(S)
- PC-Xware (T)
- Remote Dial-In (T)
- RQT (T)(S)
- Seagate Backup (T)(S)
- Secret Agent (T)

Coming

- ACOA
- AJMRR
- AMHS MM
- COMPASS
- DMS-T (T)
- FMEDIT
- GCSS
- I3
- IDM
- JDP
- JFRG II
- NICKA (T)
- NWCOMS (T)
- Secret Agent(S)
- TARGET

The abstracts are located on the following pages and on the SIPRNet at:

http://cficms.osf.disa.smil.mil:1110/aug_home/gccs301/stage2/abstracts/stage2_abstracts.html

Air Force Option 4

1. System Description

Air Force Option 4 (AFOPT4) provides GCCS 3.0.1 a direct interface to CTAPS, ATO/ACO query capabilities, and graphic and tabular displays of ATO/ACO data. AFOPT4 is comprised of three segments, GARDP, CAFMS-X(G), and Task View:

GARDP: The GCCS Air Tasking Order (ATO) Review and Dissemination Package (ARDP) and ATO Airspace Control Order (ACO) Tool (AAT), provides file management and viewing capabilities of ATO/ACOs. It accesses the CTAPS thru SMTP mail to pull the entire ATO.

CAFMS-X: The Computer-Assisted Force Management System provides GCCS users read-only access, using X-Windows, to the Contingency Theater Automated Planning System (CTAPS) via a connected Air Operations Center. It accesses the CTAPS via SQLNET queries.

Task View: The Air Force Mission Planning Systems (AFMPS) ATO Task View provides access to USMTF ATO/ACO data to query and to display non-COP, multiple graphical views of message components.

AFOPT4 tools provide an interim capability for ATO/ACO access and viewing until the fielding of Theatre Battle Management Core System (TBMCS). TBMCS, a Joint Staff program with Air Force as Executive Agent, is a DII COE compliant, joint air operations planning and execution application. It replaces non-Y2K CTAPS with a new, Y2K compliant ATO/ACO tool, which uses the joint standard USMTF 98. Therefore, it should be noted that GARDP and CAFMS-X segments will not be able to function after TBMCS is fielded, as they are dependent on CTAPS. Task View can partially function, since it uses an enhanced message format, USMTF 95-3. **NOTE:** a GCCS-TBMCS interface is required to use Task View. As of first quarter FY99, no interfaces have been scheduled for GCCS 3.0.1.

2. System Requirements

All segments of the AFOPT 4 application reside on the Solaris Platform. CAFMS-X depends on Oracle Client Applications and Netscape Web Browser. Task View and GARDP have no external software requirements

3. Users/Training

AFOPT4 was created to provide an alternative for GCCS users who receive ATO information via floppy disk or FTP. Training for AFOPT4 is developed by the Air Force and consists of interactive web-based functionality and downloading of training programs from the Air Force Web Page. Because of its limited timeline usage, AFOPT 4 training will be completed at the journeyman level only.

4. Points of Contact

The GCCS Program Management Office POC is Maj Cooper (703) 735-8611.

The GCCS Engineer POC is Cindy Hopkins (703) 735-8754.

COMPASS NT

1. System Description

COMPASS is a set of Government Off-The-Shelf (GOTS) and Commercial Off-The-Shelf (COTS) software services. COMPASS provides a non-intrusive middleware approach that facilitates Collaborative Planning, Modeling & Simulation (CPM&S) access as well as Distributed Collaborative Planning (DCP) to the Joint-Combined Arms environment. COMPASS allows planners using disparate mission planning systems to move between local planning, collaborative planning, analysis, and simulation-based rehearsal modes. COMPASS capabilities include a client-server architecture with session management (SMGT) tools, a shared overlay manager (SOM), a composite route preview (CRP) capability, COTS DCP tools, GOTS DCP server tools, and the ability to observe external M&S products on host C^4I and mission planning systems.

COMPS (SOL, NT) *[GOTS]*	The COMPASS server segment is a set of four tightly integrated servers: Session Management (SMGT), Shared Overlay Management (SOM), Composite Route Preview (CRP), and Track/Simulation Management (TSM). Each of the COMPASS servers has a companion client library that is integrated within a modeling, planning, or simulation client application (e.g., GCCS, CTAPS, AFMSS, and ModSAF). These client libraries process remote procedure calls from the client application to their companion server in order to exchange modeling, planning, and simulation data with other client applications via the COMPASS server. COMPS also provide two applications: Server Control (for starting and monitoring COMPASS sessions) and Test Client (for developmental testing or COMPASS session monitoring).
COMPC (HP, SOL, NT) *[GOTS]*	The COMPASS client library segment is a set of four statically or dynamically linkable function libraries (SMGT, SOM, CRP, and TSM). These libraries are code-integrated within a COMPASS client application and process remote procedure calls from the client application to their companion COMPASS server in order to exchange modeling, planning, and simulation data with other COMPASS client applications.
GCPA (HP, SOL) *[GOTS]*	The GCCS Collaborative Planning Application (GCPA) is a DII COE compliant application that uses the COMPASS Client Libraries (COMPC) to exchange planning, modeling, and simulation information with other COMPASS-capable systems via the COMPASS servers (COMPS). GCPA uses the DII COE Joint Mapping Tool Kit (JMTK), the Track DataBase Manager (TDBM), and the UB communications infrastructure to interface with the underlying GCCS system. Every message received from the COMPASS servers by the GCPA is processed and represented in some way to the user of the GCPA, either on the GCPA GUI or the GCCS system chart. GCPA also has menu options to launch multimedia applications such as audio, video, chat, and whiteboard.
GCPA Patch 1 HP, SOL) *[GOTS]*	GCPA Patch 1 modifies the GCCS Account Group segment (after installation of the CVWC segment) to enable launch of the CVWC application from the main menu.
CVWC (HP, SOL) *[Public Domain, licensed by Mitre]* *Version*	The Collaborative Virtual Workspace (CVW) client segment provides an intuitive method for the COMPASS user to enter and leave COMPASS sessions. CVWC automatically launches and terminates COMPASS applications to reduce workstation user workload in a distributed collaborative planning environment. See also SD, an alternate method for launching VAT and VIC/NV.
CVWC Patch 1 (HP, SOL) *[Public Domain, licensed by Mitre]*	CVWC Patch 1 modifies CVWC to enable launch and termination of GCPA and RWC as COMPASS sessions are entered or left by the workstation user. Unpatched CVWC launches and terminates only VAT and VIC.

CVWS (SOL) *[Public Domain, licensed by Mitre]* *Version*	The Collaborative Virtual Workspace (CVW) server segment provides a central administrative facility for setting up virtual conference centers and their subordinate sessions. Virtual conference centers and their sessions are accessed by CVWC.
RWS (SOL, NT) *[COTS, licensed by VisualTek Solutions, Inc]*	The Rendezvous Whiteboard server segment is the server component of an Internet/Intranet Whiteboard. RWS allows simultaneous text sessions, drawing on a shared canvas, file and document sharing, and screen and image sharing and annotation. Rendezvous provides server "channels," allowing large workgroups to share information simultaneously. Rendezvous implements GroupWare technologies such as shared whiteboards, shared documents, text communication rooms, collective browsing in a consistent work environment. Rendezvous is compatible with TCP/IP based networks.
RWC (HP, SOL, NT) *[COTS, licensed by VisualTek Solutions, Inc]*	The Rendezvous Whiteboard client segment is the client component of an Internet/Intranet Whiteboard. See RWS for additional details.
SD (HP, SOL, NT) *[Public Domain, no licensing]*	Session Directory is a multicast backbone (MBONE) application that provides (1) an easy way to create multicast sessions, (2) a facility to advertise new session(s) and (3) a dynamically updated list of available sessions (e.g., VAT audio conferences, and NV or VIC videoconferences). SD is used in COMPASS 98 as an alternate method for setting up and launching audio (VAT) and videoconferences (VIC/NV).
VAT (HP, SOL, NT) *[Public Domain, no licensing]*	Visual Audio Tool allows users to conduct host-to-host or multihost audio teleconferences over an Internet (multihost conferences require that the kernel support IP multicast). On most architectures, no hardware other than a microphone is required - sound I/O is via the built-in audio hardware.
VIC (HP, SOL, NT) *[Public Domain, no licensing]*	Primary video conferencing application for COMPASS 98. Video Conferencing (VIC) was designed with a flexible and extensible architecture to support heterogeneous environments and configurations. For example, in high bandwidth settings, multi-megabit full-motion JPEG streams can be sourced using hardware assisted compression, while over lower bandwidth environments like the Internet, aggressive low bit-rate coding can be carried out in software. VIC is based on version 2 of the Real-time Transport Protocol (RTP), which provides basic real-time media communication support. RTP is an application-level protocol and is implemented entirely within VIC -- no special system enhancements needed to run RTP. Although VIC can be run point-to-point using standard unicast IP addresses, it is primarily intended as a multiparty conferencing application.
NV *(Sun)* *[Public Domain, no licensing]*	Alternate video conferencing application for COMPASS 98. Network Video allows users to transmit and receive slow frame rate video via UDP/IP across an Internet. Video streams can be either sent point to point, or sent to several destinations simultaneously using IP multicast. Receivers need no special hardware – just an X display. Transmitters need some sort of frame capture hardware (e.g., Sun Video Card part number X1085A)
NVAT *(NT)* *[Public Domain, no licensing]*	Alternate video conferencing application for COMPASS 98. Network Video Audio Tool (NVAT) is an audio/video application for Windows 95 and Windows NT, compatible with NV and VAT. Uses RTPv1.

2. System Requirements

COMPASS has Solaris, HP and NT segments. Its additional hardware requirements are as follows:

- Video Card (e.g., Sun Part # X1085A) for video transmission using Video Conferencing (VIC) [not required for video reception]

- NTSC Video Camera for video transmission using Video Conferencing (VIC) [not required for video reception]
- Microphone for audio transmission using Visual Audio Tool (VAT)

3. Users/Training

Collaborative planners use the COMPASS application.

4. Points of Contact

The GCCS Program Management Office POC is Maj. Cooper (703) 735-8611.

The GCCS Engineer POC is LCDR Otis, (703) 735-8764.

Common Operational Picture (COP) Embedded Training

1. System Description

The Common Operational Picture (COP) embedded training consists of three segments designed to assist GCCS users in training, generating scenarios and recreating previous tactical events. A short description of the functionality for the three segments follows:

The Training (TRAIN) segment is capable of creating and conducting a broad range of training, from simple entry level sessions to dynamic, scenario-driven operations. It is fully embedded within GCCS. All GCCS functions are available and may be activated during session creation and playback.

The Scenario Generator (SCGEN) allows a user to position simulated platforms on the GCCS map, generate movement of these platforms, annotate events and save the resulting track data in OTH-T GOLD replay files. These files can be replayed with the Replay option, or with the Reconstruction and Training modules. It is used for creating scenarios as part of GCCS embedded training sessions and plans, and for setting up dispositions for planning, real operations, live exercises and “what if” analysis.

The Reconstruction (RECON) segment archives data from the GCCS Tactical Data Base Manager (TDBM) and Communications Manager. It enables the operator to recreate past tactical events on an operational GCCS system and apply tactical decision aides to this non-real time track data.

2. System Requirements

COP Embedded Training runs on the SUN/Solaris 2.5.1 platform.

3. Users/Training

COP embedded training is for all GCCS users. A subject matter expert can quickly and easily build training sessions of varying complexity without any knowledge of software development techniques, then present them as an overlay on the standard GCCS display.

4. Points of Contact

The Program Management Office POC is Major Cooper, (703) 735-8611.

The GCCS Engineering Office POC is Cindy Hopkins, (703) 735-8754.

Microsoft Front Page

1. System Description

Microsoft Front Page is a web site creation and management tool. It provides a fast and effective way to create and manage professional quality Internet or Intranet sites without programming. It makes it easy for new users and professional Web developers to build and maintain great-looking Web sites quickly. Front Page is a partial segment whose purpose is to validate that the commercial-off-the-shelf (COTS) application, Microsoft FrontPage 98, has been installed on the PC. The COTS product is installed using the licensed CD-ROM purchased by the site. This version adds the Integ directory (containing the IntegNotes and VSOutput files) and changes the $MEMORY value to 18 to reflect the value stated in the SVD. Microsoft FrontPage 98

2. System Requirements

Front Page runs on the Windows NT 4.0 operating system. The segment requires that the commercial off-the-shelf (COTS) product, Front Page 98, be installed on the target computer before the segment is installed. It the COTS software is not installed, the installation will be terminated. Individual services or GCCS sites are required to procure licensed copies of the Front Page software.

3. Users/Training

No training is required nor given.

4. Points of Contact

The Program Management Office POC is Major Partridge, (703) 735-8661.

The GCCS Engineering Office POC is LCDR Otis, (703) 735-8764.

GCSS Common Operational Picture (COP)-Combat Support Enabled (CSE)

1. System Description

The GCSS Common Operational Picture (COP)-Combat Support Enabled (CSE) is an extension to the GCCS Common Operational Picture that provides access to combat support information. This provides the warfighter a fused tactical and combat support picture utilizing one command and control application. The GCSS COP-CSE makes use of the GCSS Combat Support Data Environment (CSDE) to access multiple combat support data sources. The GCSS CSDE consists of a virtual database and the GCSS Data Model. Currently, the GCSS COP-CSE via the CSDE accesses combat support information from the Joint Total Asset Visibility (JTAV), Joint Operations Planning and Execution System (JOPES), GCCS Status of Operational Readiness and Training Systems (GSORTS), Global Transportation Network (GTN) and National Imagery and Mapping Agency (NIMA) databases. Additional combat support sources will be available to users of the GCSS COP-CSE as they as added to GCSS CSDE in the future.

2. System Requirements

The GCSS COP-CSE runs on a GCCS 3.0.3 Solaris platform. Additionally, the SUNJRE 1.0.0.1 segment is required.

Hardware requirements: SUN workstation SPARC 20 or higher.

Additionally, the GCSS COP-CSE must have SIPRnet access to the GCSS Data Brokering Environment and users of the GCSS COP-CSE must be registered GCSS users.

3. Users/Training

Training materials for the GCSS COP-CSE are under development by DISA. Initial training in the PACOM Theater will be conducted by DISA as the segments are fielded.

4. Points of Contact

The Program Management Office POC is Major Cooper, (703) 735-8611.

The GCCS Engineering Office POC is LTC Merrick, (703) 735-8783.

GRIS Web Interface (GRISWI)

1. System Description

The GRIS Web Interface (GRISWI) is a Joint Mission Application Software (JMAS) segment. It is used by the Joint Reconnaissance Centers (JRCs) at designated Unified Command sites. GRISWI provides automated support in planning, scheduling, reporting, and monitoring reconnaissance activities under the Sensitive Reconnaissance Operations (SRO) program. GRISWI maintains a near real-time status of all SRO missions and provides immediate on-line retrieval of mission, track, and message data. To accomplish this, GRISWI provides automated real-time capture and processing of Reconnaissance Information Processing System (RIPS) format messages, and maintains a mission and track database containing schedule and resultant information. GRISWI generates and releases outgoing SRO messages to the Automated Digital Network (AUTODIN) and provides on-line query and report capabilities detailing message, mission status, and scheduling information. It is used to maintain current Track Dictionary data and to generate the master copy of each new dictionary or set of change pages. GRISWI has external interfaces with the GCCS Automated Message Handling System (AMHS), and the Joint Mapping Toolkit (JMTK).

2. System Requirements

GRISWI runs on the Solaris platform.

3. Users/Training

GRISWI is used primarily by the Joint Reconnaissance Centers at designated Unified Command sites.

4. Points of Contact

The GCCS Program Management Office POC is Beverly Walker, (703) 735-8666.

The GCCS Engineering POC is Bob Marion, (703) 735-8578.

GSORTS Input
Readiness Assessment System (RAS) Input Tool

1. System Description

The GSORTS RAS Input Tool provides an icon that allows GCCS users to launch a web browser session and connect to an NT server located at the NMCC. This enables users to create, add, modify, delete, and generate unit status reports as well as create and delete unit registrations. These requirements are specified in Joint Publication 1-03.3. The Input Tool uses web-based technology with near real time processing to replace the batch-processing environment currently used for input transactions. Thus the edits will be applied to a unit's status report immediately. This ensures that a unit will receive immediate feedback on inaccuracies and incorrectly formatted submissions will not be accepted.

2. System Requirements

GSORTS RAS Input Tool runs on platforms using Microsoft Windows NT version 4.0/Service Pack 4 operating systems and has dependencies with other GCCS software segments. The Input Tool requires the Netscape Web Browser (WEBBr 4.0.3.1) and CompT.

3. Users/Training

The Joint Staff, J3 Readiness Division, is currently coordinating training for GSORTS RAS Input Tool users with the Services. Training is presently incorporated into the Users Manual. Embedded training is the eventual goal and will be developed.

4. Points of Contact

The Program Management Office POC is Major Craig Cooper, (703) 735-8611.

The GCCS Engineering Office POC is Bob Bovee, (703) 681-2566.

GSORTS Output
Readiness Assessment System (RAS) Output Tool

1. System Description

GSORTS RAS Output Tool is a user friendly, comprehensive query and reporting tool used to retrieve and analyze data from SORTS and JOPES databases. The system uses "point and click" technology and intuitive interfaces to help users arrange and filter data, accessing unit resource, training, organizational hierarchy, and commitment data. The system also has an advanced export capability to allow the use of a broad range of commercial off-the-shelf software for reporting and publishing, such as Web browsers, word processors, spreadsheets, and presentation software. Data received in the GSORTS RAS Output Tool is displayed in the GCCS-approved Web browser through a series of query screens. Users can navigate screens through a "point and click" procedure. The system also enhances the clarity of presenting unit readiness status information by color coding the displays. CINC, Service, CSA, and Joint Staff requirements were gathered in a series of Joint Application Development sessions.

2. System Requirements

The GSORTS RAS Output Tool client (RASQRY) runs on platforms using Microsoft Windows NT version 4.0/Service Pack 4 operating systems and has a dependency on Netscape Web Browser (WEBBr 4.0.3.1).

The GSORTS RAS Output Tool server (RASSVR) runs on platforms using Solaris 2.5.1 operating systems and has a dependency on the GSORTS client database segment GORA 5.0.0.1, Netsite Web Server (WEBSv 1.0.0.2), and Netscape Web Browser (WEBBr 4.0.3.1).

3. Users/Training

The Joint Staff, J3 Readiness Division, is currently coordinating training for the GSORTS RAS Output Tool users with the Services. Training is presently incorporated into the Users Manual. Embedded training is the eventual goal and will be developed.

4. Points of Contact

The Program Management Office POC is Major Craig Cooper, (703) 735-8611.

The GCCS Engineering Office POC is Bob Bovee, (703) 681-2566.

JOPES Editing Tool (JET)

1. System Description

The JOPES Editing Tool (JET) provides a capability to create, add, modify, delete and generate output on deployment-related information contained in an Operation Plan (OPLANB) tie Phased Force Deployment Data (TPFDD). This TPFDD edit capability is a critical tool for deliberate or peacetime planning and time-sensitive or Crisis Action Planning (CAP).

2. System Requirements

JET runs on the Sun/Solaris 2.5.1 platform.

3. Users/Training

JET is used by the JOPES community in the Joint Staff and Unified Command staffs.

4. Points of Contact

The GCCS Program Management Office POC is Major Cooper, (703) 735-8611.

The GCCS Engineering POC is Jane Davis, (703) 681-2582.

MAT

1. System Description

MAT is a medical planner's tool that provides a requirements generator (MAT-RG) and a course of action analysis (MAT-COAA) module. Previously, two separate models performed these functions. MAT combines these two functions into a single environment and provides interfaces between them and to other data sources and automated tools.

2. System Requirements

MAT runs on the Windows NT operating system.

3. Users/Training

MAT will be provided to medical planners at the CINC, Service, and CINC component level.

4. Points of Contact

The Program Management Office POC is Major Cooper, (703) 735- 8611.

The GCCS Engineering Office POC is LCDR Otis (703) 735-8764.

METOC JMS/MIS

1. System Description

METOC imports, processes, displays and disseminates Meteorological and Oceanographic products for layered overlay on the COP. It is a high-level decision aid/briefing tool as opposed to a forecasting tool. It provides the use of "CNN" type symbology to present environmental data to decision makers. Products include forecasts, warnings, gridded field data, satellite imagery, briefing symbology, and observations. Information is supplied on a "push/pull" basis. Operators can pull JMV bundles containing gridded field information, satellite (gif) information and observation data over the SIPRNET. Various Production, Regional and AFLOAT centers push to METOC. Users can also download data from various centers' Web pages. METOC contains six segments. Combined, they deliver the following functionality:

- **METOC Imagery** – allows viewing, animating, and management of METOC image format (MIF) files; overlay of static and animated imagery on the COP using JMTK.
- **METCOM Communications** – allows download of OTH-T Gold format weather data from Fleet numerical SIPRNET website. Downloaded data can be viewed as raw grid data and displayed on the COP.
- **GRID Draw** – allows retrieval of gridded data which can be drawn on the COP.
- **Object Plot** – allows retrieval and display of environmental data, such as wind barbs, on the COP.
- **METOC Overlays** – a draw utility which allows placing METOC symbology, text, etc., on the COP. These overlays can be transmitted to other GCCS sites.
- **Editors** – allows creating, storing, and displaying surface and air observation data on the COP. Environmental Editor allows creation, viewing, editing of Bathythermographic and Ocean profile data and placing it on the COP.
- **Brief Utility** – a PowerPoint like presentation builder which allows use of lines, text, polygons, pixmap and METOC symbols. It provides capability to create and annotate images, or pictures, and assemble them into products for electronic briefings. Graphics created can also be transmitted to other users.
- **METOC Status Board** – a presentation tool that can be displayed on the COP. It creates mission scenarios with "RED/YELLOW/GREEN" assessment of the mission based on environmental factors.
- **METOC Data Server** – Ingests and manages meteorological and oceanographic data provided from external sources. Provides services to METOC client applications desiring environmental data.
- **PARSER** – Provides message parsers, or decoders, for OTH-T Gold messages. Decodes OTH-T Gold, GRIDFLD, RDSND, BATHY, MUNIT and NUNIT messages.

2. System Requirements

METOC JMS/IMS runs on the Solaris Platform.

3. Users/Training

METOC is used by meteorological personnel who need briefing and decision aid tools.

4. Points of Contact

The GCCS Program Management Office POC is Jerry Bennett (7030 735-8282.

The GCCS Engineer POC is Cindy Hopkins (703) 735-8754.

METOC Tactical Forecast System (TFS)

1. System Description

The METOC Tactical Forecast System (TFS) segment is a weather forecast system that provides communications, data management, and base weather station capabilities on a single hardware platform. Various newly developed weather capabilities are also incorporated in TFS, including communication and product distribution functionality via the World Wide Web and graphical red-yellow-green (go-no go) theater weather charts. Web capabilities include download of Appendix 30 products from remote sits for loading into the local TFS database. In addition, this capability allows the local user to place documents from MS Word, Excel and MS PowerPoint onto the local web pages as well as image files than can be downloaded from other sites or created locally. TFS can receive weather products from the Air Force Weather Agency and other remote locations using TCP/IP and HTTP. From these input data sources, the TFS develops and maintains, in near real-time, an in-theater weather composite data set. The TFS receives, displays, creates, quality controls, and transmits weather data and other related data, in deployed areas to C^4I customers. The TFS mission application is composed of two software segments: (1) Tactical Forecast System (TFS) segment and the (2) TFS Web Application segment.

2. System Requirements

METOC TFS runs on the following Solaris platforms:

- Sun SPARCstation 20 with the Turbo GX Plus graphics card running Solaris 2.5.1.
- Sun Ultra 2 with the Creator3D graphics card running Solaris 2.5.1.

Additionally, the TFS segment must reside on a client system (i.e., must reside on the workstation that the forecaster will be physically using). Each client workstation that will be used to run TFS must have the TFS segment physically loaded.

3. Users/Training

Due to the depth of expertise required to use this application, only a trained professional forecaster who has completed the Weather System Support Cadre (WSSC) tactical weather systems training course will find this application useful.

Training for TFS applications will be made available through the Air Force Weather Agency. The depth of training will vary, based on individual experiences with forecasting tools.

4. Points of Contact

The Program Management Office POC is Jerry Bennett, (703) 735-8282.

The GCCS Engineering Office POC is Cindy Hopkins, (703) 735-8754.

Microsoft NetMeeting

1. System Description

The Microsoft NetMeeting segment provides real-time conferencing along with several additional features such as communication with both audio and video, collaboration on Windows-based applications, exchange of graphics using an electronic whiteboard, file transfers and a text-based chart program. This segment is a partial segment that verifies that the Microsoft NetMeeting software has been installed on the PC.

2. System Requirements

NetMeeting runs on the Windows NT 4.0 operating system The segment requires that the commercial off-the-shelf (COTS) product, Microsoft NetMeeting, be installed on the target computer before the segment is installed. If the COTS software is not installed, the installation will be terminated. Individual services or GCCS sites are required to procure licensed copies of the Microsoft NetMeeting software.

3. Users/Training

No training is required nor given.

4. Points of Contact

The Program Management Office POC is Major Partridge, (703) 735-8661.

The GCCS Engineering Office POC is LCDR Otis, (703) 735-8764.

Microsoft Office 97

1. System Description

Microsoft Office 97 provides a complete set of fully integrated office automation applications. This segment is a partial segment that verifies that the Microsoft Office 97 application has been installed on the PC.

2. System Requirements

Office 97 runs on the Windows NT 4.0 operating system The segment requires that the commercial off-the-shelf (COTS) product, Microsoft Office 97, be installed on the target computer before the segment is installed. In addition, the Software Release Packs one and two for Microsoft Office 97 must be installed to make Microsoft Office 97 Y2K compliant. If the COTS software is not installed, the installation will be terminated. Individual services or GCCS sites are required to procure licensed copies of the Microsoft Office 97 software.

3. Users/Training

No training is required nor given.

4. Points of Contact

The Program Management Office POC is Major Cooper, (703) 735-8611.

The GCCS Engineering Office POC is Jeff Bognar, (703) 735-8528.

PC-Xware

1. System Description

The PC-Xware segment is an X-Windows server that enables a user to display and use X Window based applications on a PC running Windows NT. PC-Xware is a partial segment whose purpose is to validate that the commercial-off-the-shelf (COTS) application, PC-Xware, has been installed on the PC. This version adds the Integ directory (containing the IntegNotes and VSOutput files) and changes the $MEMORY value to 18 to reflect the value stated in the SVD.

2. System Requirements

PC-Xware runs on the Windows NT 4.0 operating system The segment requires that the commercial off-the-shelf (COTS) product, PC-Xware, be installed on the target computer before the segment is installed. It the COTS software is not installed, the installation will be terminated. Individual services or GCCS sites are required to procure licensed copies of the PC-Xware software.

3. Users/Training

No training is required nor given.

4. Points of Contact

The Program Management Office POC is Major Partridge, (703) 735-8661.

The GCCS Engineering Office POC is Jaime Medero, (703) 681-2590.

Remote Dial-In

1. System Description

The AT&T STU III 1910 Driver (ATTSTU) software supports MS Windows NT remote access to the 1910 modem and allows for dial-up server connections from remote users. The ATTSTU software segment hosts the SDD1910 (aka AT&T Secure Data 1910 External Modem) driver software that configures the remote access dialing for modem Model(s) 1100, 2100, 4100, SDD1900, and SDD1910 hardware. This version of ATTSTU contains driver software that configures and handles Model response delays, including carrier, secure call, “failed at 14400 retrying”, “failed at 9600 retrying”, and General Dynamics Secure Communications Systems’ STUN10 Model 400/500 responses.

2. System Requirements

The Remote Dial AT&T STU III 1910 Driver (ATTSTU) runs on the Windows NT 4.0 operating system. The segment requires that the commercial off-the-shell (COTS) product, AT&T STU III 1910 Driver (ATTSTU), be installed on a Pentium Personal Computer or higher processor. ATTSTU requires an AT&T STU III modem.

3. Users/Training

No training is required nor given.

4. Points of Contact

The Program Management Office POC is Major Cooper, (703) 735-8611.

The GCCS Engineering Office POC is LCDR Otis, (703) 735-8764.

Rapid Query Tool (RQT)

1. System Description

The Rapid Query Tool (RQT) is a prototype. It consists of one segment, the RQT Client. No RQT specific database segment is required. It is intended to perform all the critical functions of legacy JOPES Ad Hoc Query (AHQ), but at a much higher speed. It is a rapid Operation Plan (OPLAN) query tool. It uses a new approach that provides a fast, flexible, and complete solution to a user's OPLAN query needs. RQT provides a wide range of user-defined data representation and format options for viewing and printing OPLAN data. RQT creates a "snapshot" of OPLAN data through rapid retrieval using parallel processing. This snapshot is saved on the Client workstation and is used when generating reports. This approach allows report tailoring "on the fly" and greatly reduces the number of times the GCCS Oracle database is accessed. RQT provides the user with a comprehensive JOPES data retrieval, analysis, and output tool. The primary goal in the development of RQT is providing the JOPES user community with a total OPLAN data analysis tool with the absolute maximum performance. Speed does not come without the application of processing power. RQT does this by taking advantage of the database server's capability to manage multiple processors and processes. RQT creates multiple processes to extract data, thus eliminating the time-consuming bottleneck of multiple ORACLE table joins. After the data is retrieved, it is then merged into a single "snapshot" for analysis. The multiple processes are prioritized and managed by the database server operating system in consideration of server demands to perform other tasks. It is to the user's advantage that the operating system puts as much computing power as available to accomplish the retrievals and merge the data. This is done quickly and efficiently as opposed to long term, slow processes that tend to bog the system down.

2. System Requirements

RQT resides on the Solaris Platform. The installation and runtime requirements are as follows: GCCS Account Group (GCCS), ORACLE Client Applications (ORAC), ORACLE Client Tools 2 (ORAT2) and TCL (TCL).

3. Users/Training

RQT was developed for the JOPES user community. Training will be included in the JOPES course by the JOPES Training Organization at Scott Air Force Base. In addition, there is excellent training information/examples contained in the Users Guide, CM 500-373-15, which can be downloaded from the DISA Homepage.

4. Points of Contact

The GCCS Program Management Office POC is Maj Cooper (703) 735-8611.

The GCCS Engineer POC is Jane Davis (703) 681-2582.

Seagate Backup

1. System Description

The Seagate Backup provides the tools to perform automated backups of critical data on Windows NT servers. This segment is a partial COTS segment that verifies that the Seagate Backup application has been installed on the PC. This version adds the Integ directory (containing the IntegNotes and VSOutput files) and changes the $MEMORY value to 18 to reflect the value stated in the SVD.

2. System Requirements

Seagate Backup runs on the Windows NT 4.0 platform.

3. Users/Training

No training is required nor given.

4. Points of Contact

The Program Management Office POC is Major Cooper, (703) 735-8611.

The GCCS Engineering Office POC is LCDR Otis, (703) 735-8764

Secret Agent

1. System Description

Secret Agent 3.1 is a file encryption utility containing implementations of the most secure and popular encryption and authentication algorithms available today. This segment is a partial segment that verifies that the AT&T Secret Agent application has been installed on the PC. This version adds the Integ directory (containing the IntegNotes and VSOutput files) and changes the $MEMORY value to 18 to reflect the value stated in the SVD.

2. System Requirements

Secret Agent runs on the Windows NT 4.0 operating system The segment requires that the commercial off-the-shelf (COTS) product, AT&T Secret Agent, be installed on the target computer before the segment is installed. If the COTS software is not installed, the installation will be terminated. Individual services or GCCS sites are required to procure licensed copies of the AT&T Secret Agent software.

3. Users/Training

No training is required nor given.

4. Points of Contact

The Program Management Office POC is Major Partridge, (703) 735-8661.

The GCCS Engineering Office POC is LCDR Otis, (703) 735-8764.

Adaptive Course of Action (ACOA)

1. System Description

The Adaptive Course of Action (ACOA) system stores plans in a Campaign Object server so that plans are available at all times to operational planners at all levels of planning and at different geographical sites. ACOA provides a distributed collaborative environment through the following segments:

Web Planner: The Web Planner consists of an integrated set of planning tools served uniformly from a web site that is accessible by a standard web browser. Web Planner planning tools are integrated at three levels, the graphical user interface level, the data representation level and the data service level.

All tools in the Web Planner toolset share a common look and feel. All tools access and manipulate the same underlying plan data, which is stored in a common object-oriented architecture and served through a CORBA-based server. Plan data used by Web Planner tools is accessible by other applets and applications through the same distributed plan service architecture.

The Dynamic Operations Planning Tool (DOPT) is a sequenced guidance tool, which takes a planner through the necessary steps of operational planning in an ordered manner. Through the DOPT, the planner inputs information, which results in the generation of standard documents and orders, selection of a CJTF, the selection of a course of action (COA), and the association of forces with a COA.

The Course of Action Selection Tool (COAST) helps the planner to specify alternative COAs for a campaign, establish criteria by which to evaluate the effectiveness of the various COAs, and perform computations, which compare and rank the COAs according to their ability to meet the selected criteria. COAST screens capture the analyses performed in COA evaluation in a color display, which is useful for inclusion in briefs and slides, to document the decision-making process.

Microsoft Office tools are integrated into the toolset for document and slide generation. Multicast collaboration tools provide the planner with VTC and whiteboard collaboration capability. Tools for force selection, TPFDD generation and scheduling are currently in development.

LEIF: The Lightweight Extensible Information Framework (LEIF) is both an application and an open software development framework. As a Command and Control (C^2) and Information Technology application, LEIF presents a client interface to the operator. As an open framework, LEIF offers lightweight, client-oriented core architecture, with no required middle-tier or server capabilities. LEIF provides the means to collect data from various sources, combine the data intelligently, and display the data in various dimensions and configurations (maps, data plots, time plots, tables, spreadsheets, etc.). Data sources, data views and other data processing tools are integrated into LEIF as independently developed LEIF extensions (i.e., plug-in modules).

Odyssey: Odyssey is a standalone Java Application that runs independently of a browser. Odyssey is a method (a way of doing) and a framework (a way of thinking) when conducting distributed collaborative planning activities. It provides an over-arching graphical interface that requires little or no training but provides a powerful context in which to do strategic level planning. Odyssey provides general collaboration services and unlimited access to other electronic tools that a planner may need in the course of his/her duties. Operational personnel can quickly find and use disparate tools in the development of complex plans, requiring input from numerous sources.

Geospatial Force Planning Tool (GFPT): GFPT provides a visual, time-phased, map-based planning environment for users to develop their operational plan. The system will allow the user to select forces and assign tasks by drawing their respective symbols on top of a digital map. The mapping environment is provided through integration of the LEIF and the COP. The user will also have the ability to select various objects/tasks and view property windows describing the object's attributes. If desired, further drill-down will be possible to follow links back to the object's data source. For example, if the user has selected a unit (ship, armored division, etc), the drill-down links will pull the unit's home page. This will display the units GSORTS data such as Readiness levels.

Virtual Situation Book (VSB)/Virtual Plan Book (VPB): VSB/VPB intelligently organizes and presents a condensed overview of a particular topic. The VSB/VPB makes use of advanced visualization formats (dynamically tailored to users) with drill-down that enable quick understanding of the important elements of a crisis situation. VSB/VPB is a multimedia container for live distributed objects (objects are connected to pertinent data sources). VSB/VPB objects are represented in multi-dimensional, hierarchical and multi-scale forms. Temporal analysis is supported. To support drill-down, VSB/VPB makes use of a Knowledge Broker Agent to intelligently access the repositories needed to elaborate the information shown by the live objects.

Intelligent Process Manager (IPM): IPM is a foundation technology for ACOA. It consists of IPM/Process Design and Reengineering (IPM/PDR) and IPM/Process Monitoring and Visualization (IPM/PMV). IPM/PDR is a process design, verification, visualization, and analysis tool with multiple means for entering a process model and with email-based facilities for importing processes specified in Excel or ProcessScript. IPM/PMV is a collaborative process monitoring and visualization tool with facilities for tracking the status of individual activities and rolling up the individual activity status to determine the status of the parent processes.

IPM/PDR is used on ACOA to define/capture, verify, and catalog component CAPE processes at multiple levels of abstraction. These component processes or process fragments are the building blocks for constructing process models for CAPE scenarios. IPM/PDR is being used to create a library of reusable ACOA process fragments (assets). This library will support the composition of a CAPE process model for a particular mission. The resulting model will be used by IPM/PMV to monitor and visualize the state and status of the overall process. It does so by rolling up the status of the individual activities (i.e. leaf nodes) and subprocesses from lower levels.

2. System Requirements

ACOA runs on the Windows NT 4.0 platform.

3. Users/Training

ACOA is intended for use by all GCCS operational planners. Training will be embedded in the ACOA system.

4. Points of Contact

The Program Management Office POC is Maj Copper, (703) 735-8611.

The GCCS Engineering Office POC is Bob Marion, (703) 735-8578.

Automated Joint Monthly Readiness Review (AJMRR)

1. System Description

The Automated Joint Monthly Readiness Review (AJMRR) program provides an automated capability supporting the Joint Staff's Joint Monthly Readiness Review (JMRR) analysis and brief-building process. Its objective is an expedited and accurate JMRR product to support Joint Staff and OSD force management and procurement issue resolution and decision making. AJMRR is the Joint Readiness Extension of the Advanced Joint Planning (AJP) ACTD. AJMRR provides the JMRR reporting community with standardized input screens, web publishing tools and the connectivity to exchange any type of readiness information. The system will also keep a database of all readiness information. This database will give users the ability to look at previous slides and make decisions based on past data. It will also assist users in analyzing trends in readiness information.

2. System Requirements

AJMRR runs on the Solaris platform.

3. Users/Training

AJMRR is used by the Joint Staff and the Joint Monthly Readiness Review reporting community.

4. Points of Contact

The Program Management Office POC is Kerry Weathington, (703) 735-8662.

The GCCS Engineering Office POC is Bob Bovee, (703) 681-2566.

AMHS Message Manager (AMHSMM)

1. System Description

AMHSMM is a specially developed application that provides a central message management and tasking system. It allows the user to access AUTODIN message traffic from the GCCS NT platform. It is the part of AMHS that resides on GCCS.

2. System Requirements

AMHSMM runs on the NT 4.0 platform.

3. Users/Training

AMHSMM is designed to aid personnel in the performance of Automated Digital Network (AUTODIN) message review, generation, coordination, and release duties.

4. Points of Contact

The GCCS Program Management Office POC is Major Cooper, (703) 735-8611.

The GCCS Engineering POC is Ken Fagan, (703) 735-8643.

COMPASS

1. System Description

COMPASS is a set of Government Off-The-Shelf (GOTS) and Commercial Off-The-Shelf (COTS) software services. COMPASS provides a non-intrusive middleware approach that facilitates Collaborative Planning, Modeling & Simulation (CPM&S) access as well as Distributed Collaborative Planning (DCP) to the Joint-Combined Arms environment. COMPASS allows planners using disparate mission planning systems to move between local planning, collaborative planning, analysis, and simulation-based rehearsal modes. COMPASS capabilities include a client-server architecture with session management (SMGT) tools, a shared overlay manager (SOM), a composite route preview (CRP) capability, COTS DCP tools, GOTS DCP server tools, and the ability to observe external M&S products on host C^4I and mission planning systems.

COMPS (SOL, NT) *[GOTS]*	The COMPASS server segment is a set of four tightly integrated servers: Session Management (SMGT), Shared Overlay Management (SOM), Composite Route Preview (CRP), and Track/Simulation Management (TSM). Each of the COMPASS servers has a companion client library that is integrated within a modeling, planning, or simulation client application (e.g., GCCS, CTAPS, AFMSS, and ModSAF). These client libraries process remote procedure calls from the client application to their companion server in order to exchange modeling, planning, and simulation data with other client applications via the COMPASS server. COMPS also provide two applications: Server Control (for starting and monitoring COMPASS sessions) and Test Client (for developmental testing or COMPASS session monitoring).
COMPC (HP, SOL, NT) *[GOTS]*	The COMPASS client library segment is a set of four statically or dynamically linkable function libraries (SMGT, SOM, CRP, and TSM). These libraries are code-integrated within a COMPASS client application and process remote procedure calls from the client application to their companion COMPASS server in order to exchange modeling, planning, and simulation data with other COMPASS client applications.
GCPA (HP, SOL) *[GOTS]*	The GCCS Collaborative Planning Application (GCPA) is a DII COE compliant application that uses the COMPASS Client Libraries (COMPC) to exchange planning, modeling, and simulation information with other COMPASS-capable systems via the COMPASS servers (COMPS). GCPA uses the DII COE Joint Mapping Tool Kit (JMTK), the Track DataBase Manager (TDBM), and the UB communications infrastructure to interface with the underlying GCCS system. Every message received from the COMPASS servers by the GCPA is processed and represented in some way to the user of the GCPA, either on the GCPA GUI or the GCCS system chart. GCPA also has menu options to launch multimedia applications such as audio, video, chat, and whiteboard.
GCPA Patch 1 (HP, SOL) *[GOTS]*	GCPA Patch 1 modifies the GCCS Account Group segment (after installation of the CVWC segment) to enable launch of the CVWC application from the main menu.
CVWC (HP, SOL) *[Public Domain, licensed by Mitre]* *Version*	The Collaborative Virtual Workspace (CVW) client segment provides an intuitive method for the COMPASS user to enter and leave COMPASS sessions. CVWC automatically launches and terminates COMPASS applications to reduce workstation user workload in a distributed collaborative planning environment. See also SD, an alternate method for launching VAT and VIC/NV.

CVWC Patch 1 (HP,SOL) *[Public Domain, licensed by Mitre]*	CVWC Patch 1 modifies CVWC to enable launch and termination of GCPA and RWC as COMPASS sessions are entered or left by the workstation user. Unpatched CVWC launches and terminates only VAT and VIC.
CVWS (SOL) [Public Domain, licensed by Mitre] Version	The Collaborative Virtual Workspace (CVW) server segment provides a central administrative facility for setting up virtual conference centers and their subordinate sessions. Virtual conference centers and their sessions are accessed by CVWC.
RWS (SOL, NT) *[COTS, licensed by VisualTek Solutions, Inc]*	The Rendezvous Whiteboard server segment is the server component of an Internet/Intranet Whiteboard. RWS allows simultaneous text sessions, drawing on a shared canvas, file and document sharing, and screen and image sharing and annotation. Rendezvous provides server "channels," allowing large workgroups to share information simultaneously. Rendezvous implements GroupWare technologies such as shared whiteboards, shared documents, text communication rooms, collective browsing in a consistent work environment. Rendezvous is compatible with TCP/IP based networks.
RWC (HP, SOL, NT) *[COTS, licensed by VisualTek Solutions, Inc]*	The Rendezvous Whiteboard client segment is the client component of an Internet/Intranet Whiteboard. See RWS for additional details.
SD (HP, SOL, NT) *[Public Domain, no licensing]*	Session Directory is a multicast backbone (MBONE) application that provides (1) an easy way to create multicast sessions, (2) a facility to advertise new session(s) and (3) a dynamically updated list of available sessions (e.g., VAT audio conferences, and NV or VIC videoconferences). SD is used in COMPASS 98 as an alternate method for setting up and launching audio (VAT) and videoconferences (VIC/NV).
VAT (HP, SOL, NT) *[Public Domain,no licensing]*	Visual Audio Tool allows users to conduct host-to-host or multihost audio teleconferences over an Internet (multihost conferences require that the kernel support IP multicast). On most architectures, no hardware other than a microphone is required - sound I/O is via the built-in audio hardware.
VIC (HP, SOL, NT) *[Public Domain, no licensing]*	Primary video conferencing application for COMPASS 98. Video Conferencing (VIC) was designed with a flexible and extensible architecture to support heterogeneous environments and configurations. For example, in high bandwidth settings, multi-megabit full-motion JPEG streams can be sourced using hardware assisted compression, while over lower bandwidth environments like the Internet, aggressive low bit-rate coding can be carried out in software. VIC is based on version 2 of the Real-time Transport Protocol (RTP), which provides basic real-time media communication support. RTP is an application-level protocol and is implemented entirely within VIC -- no special system enhancements needed to run RTP. Although VIC can be run point-to-point using standard unicast IP addresses, it is primarily intended as a multiparty conferencing application.
NV *(Sun)* *[Public Domain, no licensing]*	Alternate video conferencing application for COMPASS 98. Network Video allows users to transmit and receive slow frame rate video via UDP/IP across an Internet. Video streams can be either sent point to point, or sent to several destinations simultaneously using IP multicast. Receivers need no special hardware – just an X display. Transmitters need some sort of frame capture hardware (e.g., Sun Video Card part number X1085A)
NVAT *(NT)* *[Public Domain, no licensing]*	Alternate video conferencing application for COMPASS 98. Network Video Audio Tool (NVAT) is an audio/video application for Windows 95 and Windows NT, compatible with NV and VAT. Uses RTPv1.

2. System Requirements

COMPASS has Solaris, HP and NT segments. Its additional hardware requirements are as follows:

Video Card (e.g., Sun Part # X1085A) for video transmission using Video Conferencing (VIC) [not required for video reception]

NTSC Video Camera for video transmission using Video Conferencing (VIC) [not required for video reception]

Microphone for audio transmission using Visual Audio Tool (VAT)

3. Users/Training

Collaborative planners use the COMPASS application.

4. Points of Contact

The GCCS Program Management Office POC is Maj. Cooper (703) 735-8611.

The GCCS Engineer POC is LCDR Otis, (703) 735-8764.

Defense Message System (DMS) Microsoft Outlook 98

1. System Description

The Defense Message System (DMS) Microsoft Outlook 98 User Agent (UA) adds specific features to the commercial Outlook technology to comply with the specifications set by the United States Department of Defense (DoD). It offers messaging and groupware capabilities, and supports universal connectivity. DMS Microsoft Outlook 98 User Agent will be used for DII COE-based application segments on the Global Command and Control System (GCCS). This segment is an abbreviated segment for the NT-platform.

2. System Requirements

DMS-T Outlook 98 runs on the NT 4.0 platform.

3. Users/Training

For sending and receiving messages over networks. This user agent resides on the client, and offers FORTEZZA security capabilities (a security measure endorsed by the Department of Defense (DoD).

4. Points of Contact

The GCCS Program Management Office POC is Major Cooper, (703) 735-8611.

The GCCS Engineering POC is Ken Fagan, (703) 7351-8643.

Force Module Editor (FMEDIT)

1. System Description

Force Module Editor (FMEDIT) is an application which can create multiple levels of hierarchically arranged force modules (FM) to complement the single level of FMs in TPEDIT. FMEDIT has the capability to expand dramatically in terms of constructing FMs based on attributes such as mission, capabilities, etc, which allows much improved flexibility in deployment planning and a tighter coupling of the employment plan and the deployment plan. FMEDIT is a part of the Joint Planning and Execution Toolkit (JPET) that also includes the JTF Map System (MATT), TPFDD Editor (TPEDIT), and Theater-level Analysis, Replanning, and Graphical Execution Toolkit (TARGET) software.

2. System Requirements

FMEDIT requires Oracle Client Applications (ORAC), FMEDIT Database (FMDATA), and TPEDIT Data (TPDATA) segments to be installed on the Oracle Database Server before installation.

3. Users/Training

JPET users will use FMEDIT for collaborative planning and crisis action planning.

4. Points of Contact

The GCCS Program Management Office point of contact is Major Cooper, (703) 735-8611.

The GCCS Engineering Office point of contact is Bob Marion, (703) 735-8578.

Integrated Imagery and Intelligence (I3)

1. System Description

The GCCS Integrated Intelligence and Imagery (I3) is a tool that overlays Defense Intelligence Agency data, Order of Battle and targets on imagery using Joint Mapping Tool Kit (JMTK). I3 enhances GCCS with the ability to access military intelligence imagery assets. It provides necessary intelligence features to the warfighter and consists of 44 segments which comprise several key databases and activities. Major segments and some of the key functions are as follows:

- Imagery Management Database segment – provides for intelligence imagery by storing data on location and type of imagery
- Navy Intelligence Database- stores characteristics and performance data for aircraft, helicopters, ships, submarines and missiles
- Intelligence Database Applications - includes SQL stored procedures that enhances data retrieval supporting JMHS and Intelligence Mission applications
- General Military Intelligence Database – stores order of battle, facilities and unit data
- ICS Server – provides ability to send and receive digital imagery files over full-duplex, half-duplex and simplex communications channels
- Intelligence Database Global Data – global configuration data for DIA's MIDB applications
- Message Handling Services Sybase Data Interface – provides capability to receive messages and store message text for later use
- TC4IDB Aggregate – parent aggregate for a number of Intelligence Shared Data Servers segments. Facilitates installation of those segments

2. System Requirements

Integrated Imagery and Intelligence (I3) is hosted on the Solaris and HP platforms.

3. Users/Training

Initial training will be conducted through the use of Mobile Training Teams, tailored for I3 functionality. Lessons learned from the early CENTCOM assessment will be incorporated into future training.

4. Points of Contact

The GCCS Program Management Office POC is Bob Garland (703) 735-8936..

The GCCS Engineer POC is Mike Greifner (703) 681-2479.

Information Dissemination Management (IDM)

1. System Description

IDM tools and services assist in the identification and characterization of appropriate information and in its retrieval and delivery to appropriate users while accommodating heterogeneous communications networks with intermittent availability. IDM is that set of policies, procedures, tactics and techniques which has for its goal the provision of the "right information at the right place at the right time." IDM accomplishes this by providing profiling, cataloging and search capabilities for network based information repositories, i.e. "smart pull."

2. System Requirements

IDM runs on the Sun/Solaris 2.5.1 platform.

3. Users/Training

IDM users are comprised of the CINC and his Staff down to the Joint Task Force (JTF) components. IDM provides the capability for the warfighter and commander to determine which information is to be "dynamically forward deployed" (i.e., information moved into the theater from remote source repositories periodically and automatically based on the warfighter's profile.) The warfighter profile states the information needs of the warfighter, nominally using metadata to describe the type of information desired (e.g., weather in Germany). The profile also specifies where that information should be sent and at what frequency (i.e., every 10 days, every 8 hours). A warfighter profile may apply to an individual or group of users. Information searched and retrieved by IDM services can be generated in theater, at a CONUS garrison location, or at a national source, and can originate directly from the source generator or from a temporary storage or archive function. IDM allows information flow to be controlled according to preset priorities. This ensures that mission-critical information is provided to the warfighters in a timely and efficient manner. IDM users are Commanders who set information priorities and profiles for their AOR users and information consumers thus providing effective information awareness, access, and delivery to the warfighter.

IDM training is comprised of users manuals and associated documentation as well as planned embedded application training methods and techniques.

4. Points of Contact

The Program Management Office POC is Major Craig Cooper, (703) 735-8611.

The GCCS Engineering Office POC is Russell Smith, (703) 681-2482.

Joint Defensive Planner (JDP)

1. System Description

JDP is a mission application for preparing and evaluating Air Defense Plans. The JDP application allows the user to evaluate candidate defense strategies against theater ballistic missile, cruise missile, and aircraft attacks. Planners interact with a Graphical User Interface (GUI) to set up different air defense courses of action (CoAs), including alternative force deployments and defense priorities. Planners can evaluate air defense CoAs using analytic weapon- and sensor-coverage utilities, and force-on-force simulations. Optimization functionality may be used to produce alternative radar deployments that may subsequently be analyzed using the JDP analysis tools. JDP has the capability to produce and import a TACOPDAT message to disseminate defensive plans.

2. System Requirements

Sun SPARCstation 20 or better running Solaris 2.5.1 with at least 8 GB HD and 300 MB RAM.

3. Users/Training

The JDP application is designed to assist Theater Air and Missile Defense (TAMD) planning staffs of the commanders in chiefs (CINCs), Joint Force Commander (JFC), Area Air Defense Commander (AADC), Regional Air Defense Commander(s) (RADC), and Component Commanders in the development of operational level joint TAMD plans to counter air and missile threats.

Training for the JDP application is available through the Air Force C^2 Warrior School, Hurlburt Air Force Base, Florida.

4. Points of Contact

The Program Management Office POC is Bob Garland, (703) 735-8936.

The GCCS Engineering Office POC is Lt Col Merrick, (703) 735-8683.

Joint Forces Requirements Generator (JFRG) II

1. System Description

Joint Forces Requirements Generator (JFRG) II is a PC application to support remote and forward deployed users in generating Time Phased Force Deployment Data (TPFDD). JFRG provides a unit-level deployable, microcomputer-based deployment planning tool for the Joint community. JFRG accelerates the development, sourcing, analysis, and refinement of plans and deployment databases resulting in executable JOPES TPFDD. It will provide a bridge between JOPES and the TCAIMS II system, and reduce response time by more efficiently creating and refining plans that can be accomplished directly in JOPES. JFRG prepares timely initial estimates through the use of standard reference data and analysis tools. It facilitates identification of accurate unit data down to the unit personnel and Level 4 cargo detail. It consolidates joint and service-specific reference information and codes from numerous sources. JFRG can produce JOPES executable TPFDDs, a JOPES transaction file for modifications to an existing OPLAN database, and can download existing JOPES plans.

2. System Requirements

JFRG operates on an NT 4.0 platform.

3. Users/Training

JFRG is utilized by the joint planning community. JOPES users are not anticipated to have problems using JFRG and manuals will be distributed with the software. The developer will train the DISA (D3) Mobile Training Teams (MTTs) and the MTTs are to provide on-site training as required.

4. Points of Contact

The GCCS Program Management Office POC is Maj Cooper (703) 735-8611.

The GCCS Engineer POC is Maj Howell (703) 735-8631.

Nickname, and Exercise Term system (NICKA)

1. System Description

The Code Word, Nickname, and Exercise Term system (NICKA) is designed to fully automate the OSD requirement for maintenance of code words, nicknames, exercise terms and reconnaissance nicknames data by the Joint Staff. NICKA maintains records of all reported code words and their status, all reconnaissance nicknames used at the Joint Reconnaissance Center, all exercise terms, and all currently authorized nicknames. The system validates code word and nickname usage with assigned agencies and ensures that authorized nicknames and code words are not duplicated. The NICKA transaction provides a way to register and maintain the currency of code words, nicknames, and exercise terms. NICKA uses a three-tiered architecture: client, server, and database. The three segments that make up NICKA (NICKO, NICKCL and NICKDB) are described below. NICKO has two components. One component provides all HTML, Java class, and script files necessary to display information to the users and accept their inputs from a Java-supported web browser. The other component is the server-side application that accepts client-provided information, uses it to query the database, and returns the resulting information to the client. The NICKA Online Client segment (NICKCL) is designed to provide the icon for the user's GCCS Common Desktop Environment (CDE) to launch the NICKA Online Web Application. At the NMCC, each authorized user must be entered in the NICKA database before the user can access the application with the icon. When the icon is launched, the application validates the user and the web browser will display the initial entry screen for which the user is authorized to access the application. The initial screen displayed is based on the user's type: **retrieval (R), update (U) or maintenance (M)**. The NICKA Database segment (NICKDB) builds the NICKA Oracle tables and loads data into the tables to support the NICKA Online Web Application. This segment will reside on the database server at the NMCC.

2. System Requirements

NICKA segments are developed for the Sun/Solaris platform.

3. Users/Training

GCCS(T) users will include the National Command Authorities (NCA) and the CINCs. GCCS training coordinator and NMCC mobile training teams are currently coordinating training curriculum and presentation.

4. Points of Contact

The GCCS Program Management Office POC is Maj. Partridge (703) 735-8661.

The GCCS Engineer POC is Jaime Medero (703) 681-82590.

Nuclear Weapons Contingency Operations Module Server (NWCOMS)

1. System Description

The Nuclear Weapons Contingency Operations Module Server (NWCOMS) provides summarized information regarding the status, location, and condition of U.S. nuclear weapons. It is made up of two segments, NWCOM and NWCOMS, the client and server respectively, and is part of the GCCS-T application.

2. System Requirements

NWCOMS is intended for the Solaris 2.5.1 Operating System running on Sun Microsystem servers. It requires access to the SIPRNET.

3. Users/Training

NWCOMS is used by Defense Threat Reduction Agency staff, Joint Staff and Unified Command staffs for planning and operations as required.

4. Points of Contact

The GCCS Program Management Office POC is Maj Partridge, (703) 735-8661.

The GCCS Engineering POC is Jeff Bognar, (703) 73

Secret Agent

1. System Description

Secret Agent 3.1 is a file encryption utility containing implementations of the most secure and popular encryption and authentication algorithms available today. This segment is a partial segment that verifies that the AT&T Secret Agent application has been installed on the PC. This version adds the Integ directory (containing the IntegNotes and VSOutput files) and changes the $MEMORY value to 18 to reflect the value stated in the SVD.

2. System Requirements

Secret Agent runs on the Windows NT 4.0 operating system The segment requires that the commercial off-the-shelf (COTS) product, AT&T Secret Agent, be installed on the target computer before the segment is installed. If the COTS software is not installed, the installation will be terminated. Individual services or GCCS sites are required to procure licensed copies of the AT&T Secret Agent software.

3. Users/Training

No training is required nor given.

4. Points of Contact

The Program Management Office POC is Major Partridge, (703) 735-8661.

The GCCS Engineering Office POC is LCDR Otis, (703) 735-8764.

Theater Analysis Replanning and Graphical Education Toolkit (TARGET)

1. System Description

TARGET is a set of applications designed to assist, in a distributed and collaborative environment, the employment planning process under crisis action conditions at the CJCS and CINC (strategic and theater/operational) levels. It is normally included as part of the Joint Planning and Execution Toolkit (JPET).

2. System Requirements

TARGET runs on Solaris and HP Platforms. The TARGET segment installation requirements are that Objectivity/DB (OBJECT) 4.0.10 and Perl (PERL) 5.0 are already installed. Run-time requirements are that Force Module Editor (FMEDIT), JTF Map System (MATT), Netscape Web Browser (WEBBr), Orbix (IT) 2.2c, and Applix (AST) must be installed for various TARGET functions to be useable.

The user organization will be responsible for obtaining software licenses for Orbix 2.2, Oracle 7.3.2 and Applix.

3. Users/Training

Sites supporting Joint Staff, Service Headquarters, Unified Commands, Joint Task Force Headquarters, and Service Component Commands and JPET users, for crisis action planning and collaborative planning, will use TARGET.

4. Points of Contact

The GCCS Program Management Office point of contact is Major Cooper, (703) 735-8611.

The GCCS Engineer point of contact is Bob Marion, (703) 735-8578.

(This Page Intentionally Left Blank)

Appendix 6G
The DII COE (from the I&RTS, v. 4.0)

The DII COE[62] originated with a simple observation about command and control systems: certain functions (mapping, track management, communication interfaces, etc.) are so fundamental that they are required for virtually every command and control system. Yet these functions are built over and over again in incompatible ways even when the requirements are the same, or vary only slightly, between systems. If these common functions could be extracted, implemented as a set of extensible low-level building blocks, and made readily available to system designers, development schedules could be accelerated and substantial savings could be achieved through software reuse. Moreover, interoperability would be significantly improved because common software is used across systems for common functions, and the functional capability only needs to be built correctly once rather than over and over again for each project.

This observation led to the development of the DII COE. Although its roots are in the C^4I arena, the DII COE and its principles are not unique to C^4I. The DII COE has been expanded to encompass a range of other functional areas including logistics, transportation, base support, personnel, health affairs, and finance. All new Defense Information Systems Agency (DISA) systems are being built using the DII COE while existing DISA systems are being migrated to use the DII COE. The Office of the Secretary of Defense (OSD) has recently issued a directive[63] that requires JTA compliance and, indirectly, use of the DII COE.

A significant aspect of the COE challenge is to strategically position the architecture so as to be able to take advantage of technological advances. At the same time, the system must not sacrifice quality, stability, or functionality already in the hands of the warrior. In keeping with current DoD trends, the COE emphasizes use of commercial products and standards where applicable to leverage investments made by commercial industry.

A Brief History of the DII COE

Initial DII COE development was driven by a near-term requirement to build a suitable World-Wide Military Command and Control System (WWMCCS) replacement. To achieve the near-term WWMCCS replacement objective, technical experts and program managers from the Services, intelligence community, Defense Mapping Agency (DMA), and other interested agencies met for several months beginning in the fall of 1993. Participants proposed candidate systems as a possible starting point for a COE architecture or as a suitable candidate for providing capabilities to meet WWMCCS replacement requirements. None of the candidate systems met all requirements, but it was clear that a combination of the “best” from several systems could produce a near-term system that would be suitable for WWMCCS replacement.

---

[62] The acronyms “DII COE” and “COE” are used interchangeably throughout this document. Other COEs have been created in the past (such as the Joint Maritime Information System (JMCIS) COE), which were very similar in scope or implementation with the DII COE. To avoid confusion, unless otherwise indicated, “COE” always refers to the DISA DII COE.

[63] OSD Directive dated 22 August 1996 (Subject: Implementation of the DOD Joint Technical Architecture). The directive states: all new C4I systems and other systems that interface to C4I systems shall be in compliance with the *JTA*. The *JTA* in turn mandates use of the DII COE. The *JTA* is being expanded in scope to address weapons systems as well.

Moreover, an infrastructure could be put into place and a migration strategy defined to preserve legacy systems until migration to the intended architecture could be realized.

The cornerstone architectural concept jointly developed during that series of meetings was the Global Command and Control System (GCCS) COE. This initial COE was limited in scope to address the immediate C^4I problem (i.e., WWMCCS replacement), but its principles, structure, and foundation deliberately went far beyond just the C^4I mission domain. The GCCS COE was composed of software contributed from candidate systems evaluated by this original Joint engineering team.

An initial proof-of-concept system, GCCS 1.0, was installed in early 1994 at one site to validate the approach and to receive early feedback. GCCS 1.1 followed in the summer of 1994 and was the first attempt to integrate software from Service programs as initial GCCS COE components. GCCS 1.1 included mission applications from other programs operating in a “federated” mode. That is, the mission applications were integrated together so as to be able to run on the same hardware without interfering with each other, but not yet able to effectively share data between applications. GCCS 1.1 was installed and tested at beta sites and used at certain operational sites to monitor events during the 1994 Haiti crisis. GCCS 2.0 fielding began in early 1995 at a number of operational sites. GCCS 2.1 was fielded in mid-1995 and by mid-1996 had successfully replaced WWMCCS. A prototype version of GCCS 2.2 was the basis for the 1995 Joint Warrior Interoperability Demonstration (JWID 95) and a refinement of it was the basis for JWID 96. Another GCCS 2.2 enhancement was placed in theater to support Bosnia operations and for contingency planning when tensions in the Gulf area increased in mid-1996.

In mid-1995 technical experts met under DISA guidance to expand the GCCS COE into the DII COE. The DII COE was then expanded to address other mission domains. Much of the original software has been updated to take advantage of further technological advances and Commercial Off-the-Shelf (COTS) software has replaced some of the original Government Off-the-Shelf (GOTS) components. From this historical perspective, the GCCS COE can be viewed as a subset of the much larger DII COE. Although GCCS succeeded in replacing the aged WWMCCS, it is important to realize that GCCS is far more than just a WWMCCS replacement.

In 1996, the Air Force Electronic Systems Command (ESC) at Hanscom AFB began exploring the applicability and viability of DII COE concepts to real-time systems. In the spring of 1997, based upon exploratory work begun at ESC, representatives from the Air Force, Army, and Navy met to discuss the high correlation of real-time requirements across the services. In July 1997, the Air Force, Army, Navy, and Marine Corps jointly petitioned DISA to charter a DII COE Real-time Technical Working Group (TWG). The objective of the TWG would be to develop a set of common requirements and recommendations for potential products to provide real-time capabilities, thus expanding the scope of the DII COE to include real-time systems. DISA approved the Services’ request, and the Real-time TWG began meeting in August 1997. It is anticipated that real-time services will be included in release 5.0 of the DII COE, and will be included in the next major release of the *I&RTS*.

The DII COE has its roots in command and control, but the principles and implementation described in this document are not unique to, nor limited to, command and control or logistics applications but are readily applicable to many other application areas. The specific software

components selected for inclusion in the COE determine the mission areas that the COE can address.

The DII COE Concept

The DII COE concept is a new approach that is much broader in scope than software reuse. Most software reuse approaches to date have proven less than satisfactory. Reuse approaches have generally emphasized the development of a large software repository from which designers may pick and choose modules or elect to rebuild modules from scratch. It is not sufficient to have a large repository, and too much freedom of choice leads to interoperability problems and duplication of effort. This rapidly negates the advantages of software reuse.

Software reuse strategies have also ignored the importance of data reuse. The approach has traditionally been to encapsulate data into a relational database from which applications may retrieve the data according to their own view (i.e., schema). While this approach was a tremendous advance, it fell short of the goal of providing truly interoperable systems in the Joint arena. What is required is an approach that promotes data sharing within systems and between systems. The approach must also recognize and resolve the issues of duplicative data, inconsistencies in the data, and data replication. The Shared Data Engineering (SHADE) component is the data reuse strategy for the DII COE.

The DII COE emphasizes both software reuse and data reuse, and interoperability for both data and software. But its principles are more far-reaching and innovative. The COE concept encompasses:

- An architecture and approach for building interoperable systems
- A minimal but extensible security architecture and a set of security services
- an environment for sharing data between applications and systems
- An infrastructure for supporting mission-area applications
- A rigorous definition of the runtime execution environment
- A reference implementation on which systems can be built
- A collection of reusable software components and data
- A rigorous set of requirements for achieving DII compliance[64]
- An automated toolset for enforcing COE principles and measuring DII compliance
- An automated process for software integration
- An approach and methodology for software and data reuse
- A set of Application Program Interfaces (APIs) for accessing COE components

This document is an engineering specification that describes *how* modules must interact in the target system. System architects and software developers retain freedom in building the system, but runtime environmental conflicts and data conflicts are identified and resolved through automated tools that enforce COE principles. An important side effect is that traditional integration tasks largely become the responsibility of the developer. Developers are required to

[64] The term “DII compliance” is preferred instead of “COE compliance” and is used throughout the *I&RTS*. The compliance concept and approach has not changed, but compliance is measured for segments within the COE as well as mission-application segments that lie outside the COE. Therefore, “DII compliance” is more descriptive and correct than “COE compliance.”

integrate and test their software with the COE prior to delivering it to the government. This simplifies integration because those who best understand the software design (the original developers) perform it, it reduces the cost because integration is performed earlier and at a lower level in the process, and it allows the government to concentrate on validation instead of integration.

The COE must be understood as a multi-faceted concept. Understanding how the many facets interact is important to appreciate the scope and power of the DII COE and to avoid confusion in understanding COE material. The next subsections deal with four specific facets in more detail:

- The COE as a system foundation
- The COE as an architecture
- The COE as a reference implementation
- The COE as an implementation strategy

Failure to understand these facets will lead to confusion and non-compliant systems.

The DII COE as a System Foundation

The DII COE is *not* a system; it is a foundation for building systems. Figure 6G-1 is a simplified diagram that shows how the DII COE serves as a foundation for building multiple systems. Details such as specific COE components, databases, and the internal structure of the COE have been omitted for clarity. Chapter 2 provides this level of information and describes the COE in much more detail. The purpose of Figure 6G-1 is to introduce the concept.

The large outermost shaded box in Figure 6G-1 shows two types of reusable software: the operating system and COE components. For the present discussion, it is sufficient to note that COE components are accessed through APIs and that the COE components form the architectural backbone of the target system. The API is the means through which a system permits a programmer to develop applications through interaction with the underlying COE. Standards (*POSIX* [*Portable Operating System for Information Exchange*] in the diagram) and specifications (*TAFIM* [*Technical Architecture Framework for Information Management*], *JTA* [*Joint Technical Architecture*], *I&RTS* [*Integration and Runtime Specification*], and *User Interface Specification* [*UIS*] in the diagram) dictate how COE components are to be built and how external components must be built to be compliant with the COE architecture.

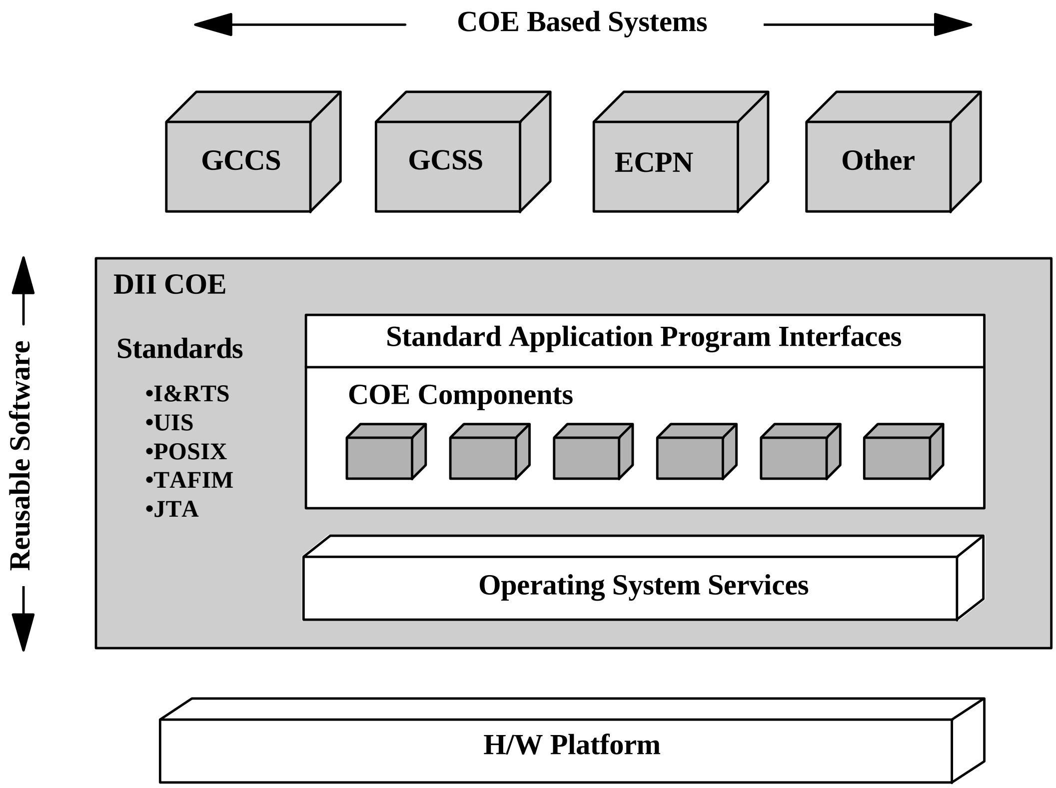


Figure 6G-1. *DII COE and COE-Based Systems*

Building a target system includes combining COE components with mission-specific software. The COE infrastructure manages the flow of data through the system, both internally and externally. Mission-specific software is mostly concerned with requesting data from the COE and then presenting it in a form that is most meaningful to the operator (e.g., as a pie chart, in tabular form, as a graph). The COE provides the necessary primitives for such data whether it is stored locally, or whether it is accessed remotely across a Local Area Network (LAN) or Wide Area Network (WAN). This frees the system designer to concentrate on meaningful data presentation and not on the mechanics of data manipulation, network communications, database storage, etc.

There is only one COE regardless of the target system. The COE is a set of building blocks. System designers select those building blocks (e.g., COE components) required for their mission application, while excluding building blocks that are not required. Each derived system uses the same set of APIs to access common COE components, the same approach to integration, and the same set of tools for enforcing COE principles. For common functions (e.g., communications interfaces, dataflow management), each target system uses precisely the same COE software components. Compliant systems do not implement their own versions of algorithms within the COE because this will rapidly lead to interoperability problems as algorithms are interpreted differently or because systems fail to upgrade algorithms at the same time. This approach to

software reuse significantly reduces interoperability problems because if the same software is used, it is not possible to have two systems that interpret or implement standards differently.

The DII COE as an Architecture

The DII COE is a network-centric[65] "plug and play" open architecture, presently designed and implemented around a client/server model. Functionality is easily added to or removed from the target system in small manageable units called *segments*. Segments are defined in terms of functions that are meaningful to operators, not in terms of internal software structure. Structuring the system into segments in this manner allows flexibility in configuring the system to meet specific mission needs or to minimize hardware requirements for an operational site. Site personnel perform field updates by replacing affected segments through use of a simple, consistent, graphically oriented user interface.

The DII COE model is analogous to the Microsoft Windows® paradigm. The idea is to provide a standard environment, a set of standard off-the-shelf components, and a set of programming standards that describe how to add new functionality to the environment. The Windows paradigm is one of "federation of systems" in that properly designed applications can coexist and operate in the same environment. But simple coexistence is not enough. It must be possible for applications to share data. The DII COE extends the Windows paradigm to allow for true "integration of systems" in that mission applications share data at the server level.

Federation versus integration is an important architectural distinction. However, integration is not possible without strict standards that describe how to properly build components to add to the system. This applies equally to software functions and data. This document and other related documents detail the technical requirements for a well-behaved, DII-compliant application. The COE provides automated tools to measure compliance and to pinpoint problem areas. A useful side effect of the tools and procedures is that software integration is largely an automated process, thus significantly reducing development time while automatically detecting potential integration and runtime problem areas.

More precisely, to a developer the DII COE includes each of the following:

- **An Architecture[66]:** A precisely defined *TAFIM* and *JTA*-compliant architecture for how system components will interact and fit together and a definition of the system-level interface to COE components.
- **A Runtime Environment:** A standard runtime operating environment that includes "look and feel," operating system, and windowing environment standards. Since no single runtime environment is possible in practice, the COE architecture provides facilities for a developer to extend the environment in such a way as to not conflict with other developers.

---

[65] The COE is truly network-centric in its design and current implementation. Fielded COE-based systems are typically designed to take advantage of this fact. However, additional development is required to provide all the tools that would be useful to fully support a network-centric system.

[66] The *JTA* describes three types of architectures: operational, technical, and system. The DII COE is relevant to all three types but does not and cannot provide a complete architectural definition for all three types. For example, the operational architecture also includes consideration of the command echelon and reporting structure. This is dictated by policy and is thus outside the scope of the COE. The DII COE is limited to addressing those aspects of an architecture that can be implemented in hardware and software as dictated by higher level standards, concept of operations, and service doctrine.

- **A Data Environment:** A standard data environment that prescribes the rules whereby applications can share data with other applications.
- **A Reference Implementation:** A clearly defined set of already implemented, reusable functions. A set of reusable software and data is a cornerstone of the DII COE product.
- **A Set of APIs:** A collection of interfaces[67] for accessing COE components. Thus, the COE is a set of building blocks in the same sense that X Windows and Motif are building blocks for creating an application's Graphical User Interface (GUI).
- **A Set of Standards and Specifications:** A set of rules that describe how to use the COE, how to construct segments, how to create a GUI, etc.
- **A Development Methodology:** A process for developing, integrating, and distributing the system and a process for sharing components with other developers. The COE emphasizes and encourages incremental development that has the advantage of quickly producing usable functionality.

The DII COE as a Reference Implementation

The COE necessarily includes an implementation of the components defined to be in the COE. The reference implementation is the key to reusability and interoperability. Use of the reference implementation provided is required to assure interoperability and is therefore a fundamental requirement for DII compliance. The reference implementation may change over time to take advantage of new technologies or to fix problem reports, but improvements are introduced incrementally while preserving product stability.

The term *reference implementation* should be properly understood in the context of the DII COE. It means that a single body of code has been used as a starting point for implementing the COE on a specific hardware platform and operating system. The only differences in the actual executable binary code are those that arise purely as a result of porting from one platform to another. The algorithms and the way the algorithms are implemented are identical from platform to platform.

The DII COE as an Implementation Strategy

The COE is also an evolutionary acquisition and implementation strategy. This represents a departure from traditional development programs. It emphasizes incremental development and fielding to reduce the time required to put new functionality into the hands of the warrior, while not sacrificing quality nor incurring unreasonable program risk or cost. This approach is sometimes described as a "build a little - test a little - field a lot" philosophy. It is a process of continually evolving a stable baseline to take advantage of new technologies as they mature and to introduce new capabilities. But the changes are done one step at a time so that the warfighters always have a stable baseline product while changes between successive releases are perceived as slight. Evolutionary development has become a practical necessity for many development programs because the traditional development cycle time is longer than the technical obsolescence cycle time. This approach allows program managers the option of taking advantage of recently developed functions to rapidly introduce new capabilities to the field, or of

[67] The term "API" is used in the DII COE context to refer to any well-defined interface between components. It may refer to a C function call, a data file format, a callable executable program, etc.

synchronizing with COE development at various points for those situations where incremental upgrades are not readily acceptable to the customer community.

The COE implementation strategy is carefully structured to protect functionality and data contained in legacy systems so that over time they can migrate to full COE utilization. Legacy systems must use only "public" APIs and migrate away from use of "private" APIs. Public APIs are those interfaces to the COE that will be supported for the life cycle of the COE. Private APIs are those interfaces that are supported for a short period of time to allow legacy systems to migrate from unsanctioned to sanctioned APIs. All new development is required to use only public APIs and use of any other APIs results in a non-DII compliant segment.

From the perspective of a system developer, whether developing a new application or migrating an existing one, the present DII COE implementation is an open client/server architecture that offers a collection of services and already-built modules for mission applications. Thus, the developer's task is to assemble and customize[68] existing components from the COE while developing only those unique components that are specific to particular mission's requirements. These additional mission-unique components must still adhere to the standards specified in the *JTA* and this document. In many if not most cases, this amounts to adding new "pull-down menu entries and icons."

Lessons Learned

The COE as the embodiment of an architectural concept offers the opportunity to leverage a mature, proven, field-tested software base for a wide variety of applications for the services, agencies, and Joint community. As budgets shrink and as budgetary priorities shift, program managers require the ability to continue to respond rapidly with systems that satisfy the information needs of United States and Allied Armed Forces. The COE implementation strategy is a significant advancement in fulfilling this ongoing need.

Examination of state-of-the-art development in light of these realities results in a set of fundamental tenets that greatly influence the history, future, and direction of the DII COE. An explanation of these tenets is useful in understanding the COE as a whole.

- **Pre-COE practices lead to development and redevelopment of the same functionality across systems.** Redevelopment is frequently necessary because of technological changes as algorithms are improved or as hardware becomes faster and cheaper. However, development cost tends to be high due to a lack of coordination between programs that share common requirements.
- **Security must be designed into the architecture.** The increasing importance placed upon system security has underscored the need to view security as an engineering discipline. Security considerations must be addressed throughout the entire system life cycle from requirements analysis through maintenance. It is not sufficient to "add security" after fielding or even after development.
- **Duplication of functionality within the same system is more expensive than avoiding duplication.** Lack of coordination between program developers is a fundamental cause for

[68] Customization is achieved in two ways: by omitting COE components that are not required and by configuring operational characteristics of the selected COE components. Customization does *not* mean the ability to change the functional operation of the component (a) outside the configurable items provided by the component or (b) outside the facilities provided by the component's APIs. When customizing the COE is discussed in this document, it must be understood in this context as a way of tailoring the COE to meet a specific mission need.

duplicative functions, but an additional factor is that reuse libraries are not commonly available. The impact of duplication is more than just program costs. When functionality is duplicated, system users are often given conflicting information even in the presence of identical data because designers took slightly different approaches to solving the same problems or made slightly different assumptions.

- **Interoperability is not achievable through "paper" standards alone.**[69] Standards are necessary, but not sufficient,[70] to guarantee interoperability. Interoperability problems are generally not caused by the standards chosen but by differing or incorrect interpretations of standards. System designers often choose different standards with which to comply, but even when the standards are the same, different interpretations of the standards can greatly change the way the resulting system operates. The COE emphasizes use of industry and government standards, but relies even more on automated ways of measuring and evaluating compliance, and thus quantitatively evaluating program risk. The only practical way to achieve interoperability is to use exactly the same software, written to appropriate standards, for common functions across applications. For example, the COE contains a common tactical track correlator to ensure that all users see the same tactical picture. The answer produced by the correlator may be incorrect but a problem correction in one place then becomes effective for all users.
- **Pre-COE practices lead to exponential growth in testing and associated development costs.** Lack of commonality and modularity in system building blocks means that there is much duplication of effort in testing basic functionality and testing in one section of a system is often tightly coupled to testing in another section. This complicates and extends the certification process. Configuration management, system integration, and long-term maintenance are also more complex and costly when there is a lack of commonality and modularity in system building blocks.
- **The importance of training is usually underestimated and the magnitude of the training problem is increasing.** An operator is often expected to use multiple systems that behave completely differently, are equally complex with their own subtleties, and that give slightly different answers. Operator turnover is rapidly reaching the point where the time it takes to train an operator is a significant portion of the time that the operator is assigned to his current tour of duty. Training is greatly reduced by a consistent "look and feel" and by the ability to present to the operator only those functions useful for the task at hand.
- **Don't reinvent the wheel.** If a component already exists, it should probably be utilized even if the component is not the optimum solution. Almost any module can be improved but that is rarely the issue. Reuse of existing and proven software and data structures allow focus of attention on mission uniqueness. Rather than concentrating scarce development resources on recreating building blocks, the resources can be more appropriately applied to configuration and development of functionality and data structures that are not already available.
- **Utilize existing commercial standards, specifications, and products whenever feasible.** The commercial marketplace generally moves at a faster pace than the military marketplace and advancements are generally available at a more rapid rate. Use of commercial products has several advantages. Using already built items lowers production costs. The probability of product enhancements is increased because the marketplace is larger. The probability of standardization is increased because a larger customer base drives it.

[69] This statement is not meant to minimize the importance of standards, but to state that they alone are not sufficient to solve interoperability problems. The situation would be far more desperate in the absence of standards.

[70] The solution provided by the COE is to define specifications and a reference implementation of a standard. For example, in the user interface area, Motif is the standard selected for UNIX platforms and the *User Interface Specifications for the DII* is the specification written to be compliant with Motif, but tailored for the particular mission domain.

Requirements and Objectives

The following requirements apply to the DII COE:

- The DII COE will be fully compliant with the JTA[71]. Standards defined within the JTA promote an open systems architecture, the benefits of which are assumed to be well known and generally accepted.
- The DII COE is intended to be hardware independent and operate on a range of open systems platforms running under standards-based operating systems. Program-driven requirements, associated testing costs, and funding will dictate which specific hardware platforms are given priority.
- Non-developmental items (NDIs), including both COTS and GOTS products, are the preferred implementation approach.
- The DII COE is programming-language neutral. It does not state a preference of one language over another, but leaves the selection of a programming language to higher-level standards profile guidance and programmatic considerations. Any statements in the I&RTS which appear to state or imply a preference for one language over another are unintentional.

COE development is driven by C^{4}I for the warrior requirements as articulated by the services through the appropriate DISA Configuration Control Board (CCB) process. Development priorities are established by the CCB Chair and given to the DII COE Chief Engineer for implementation.

The broad program drivers for the DII COE lead to a number of program objectives that include those stated in the *TAFIM, Volume 2*:

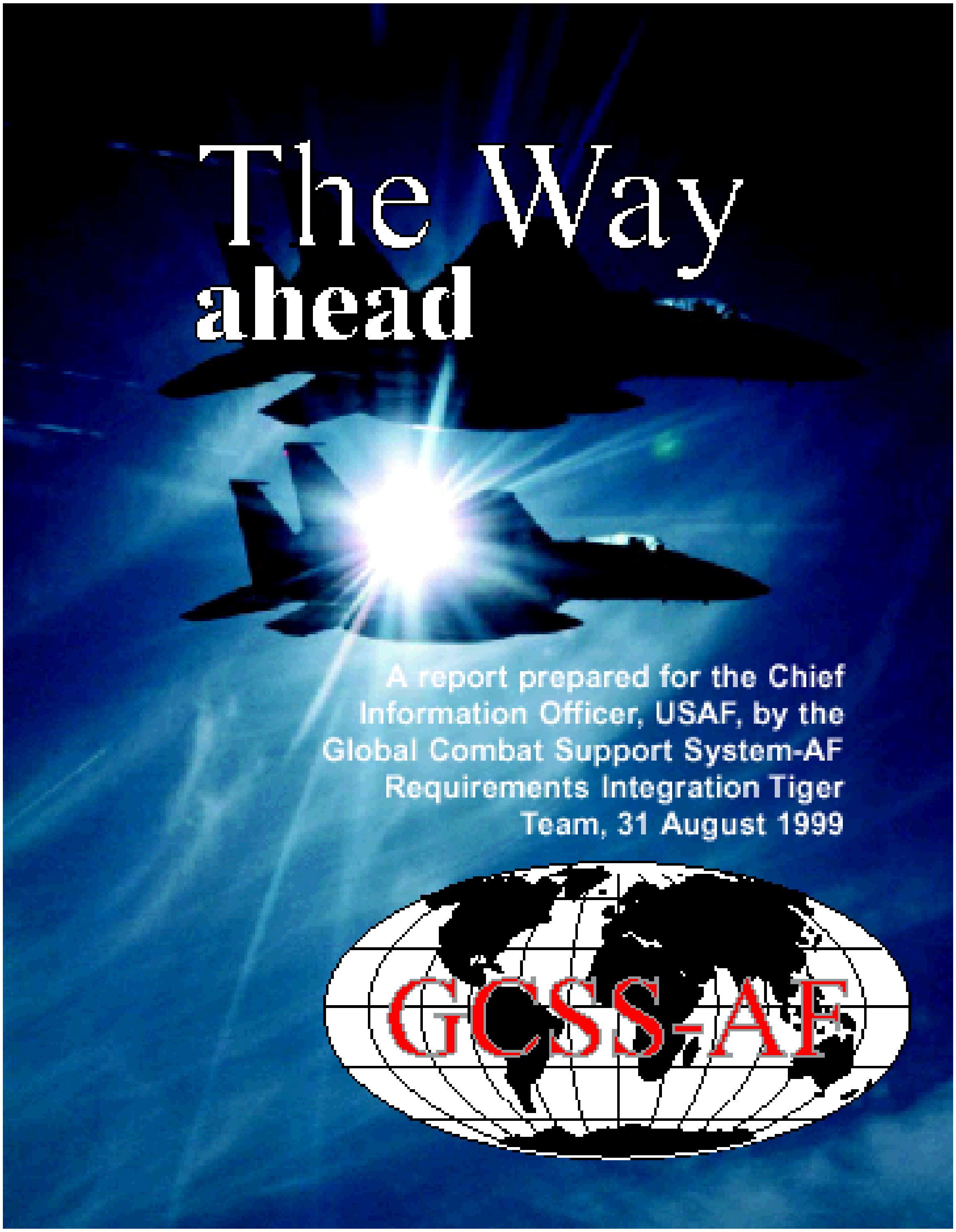
- **Commonality**: Develop a common core of software that will form the foundation for Joint systems, initially for C^{4}I and logistics systems.
- **Reusability**: Develop a common core of software that is highly reusable to leverage the investment already made in software development across the services and agencies.
- **Standardization**: Reduce program development costs through adherence to industry standards. This includes use of commercially available software components whenever possible.
- **Engineering Base**: Through standardization and an open architecture, establish a large base of trained software/systems engineers.
- **Training**: Reduce operator training costs and improve operator productivity through enforcement of a uniform human-machine interface, commonality of training documentation, and a consistent "look and feel."
- **Interoperability**: Increase interoperability through common software, common data structures, and consistent system operation.
- **Scalability**: Through use of the segment concept and the COE architectural infrastructure, improve system scalability so that COE-based systems will operate with the minimum resources required.
- **Portability**: Increase portability through use of open systems concepts and standards. This also promotes vendor independence for both hardware and software.

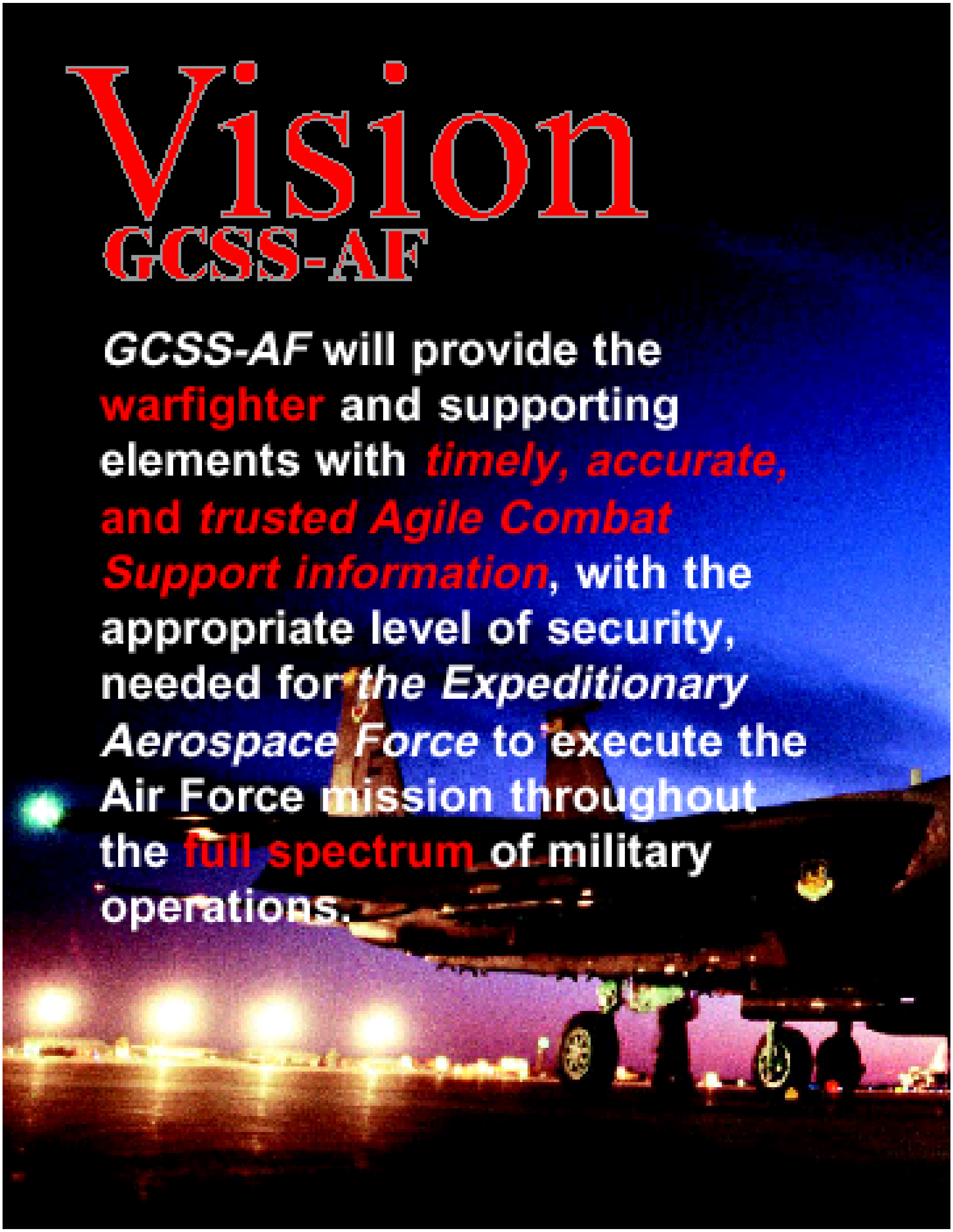
[71] *JTA* replaces some of the standards guidance in the *TAFIM* as per OSD directive (Subject: Implementation of the DOD Joint Technical Architecture) dated 22 August 1996. It replaces those standards for service areas defined within the *JTA*. For those service areas not included in the *JTA*, guidance in Volume 7 of the *TAFIM* is to be followed.

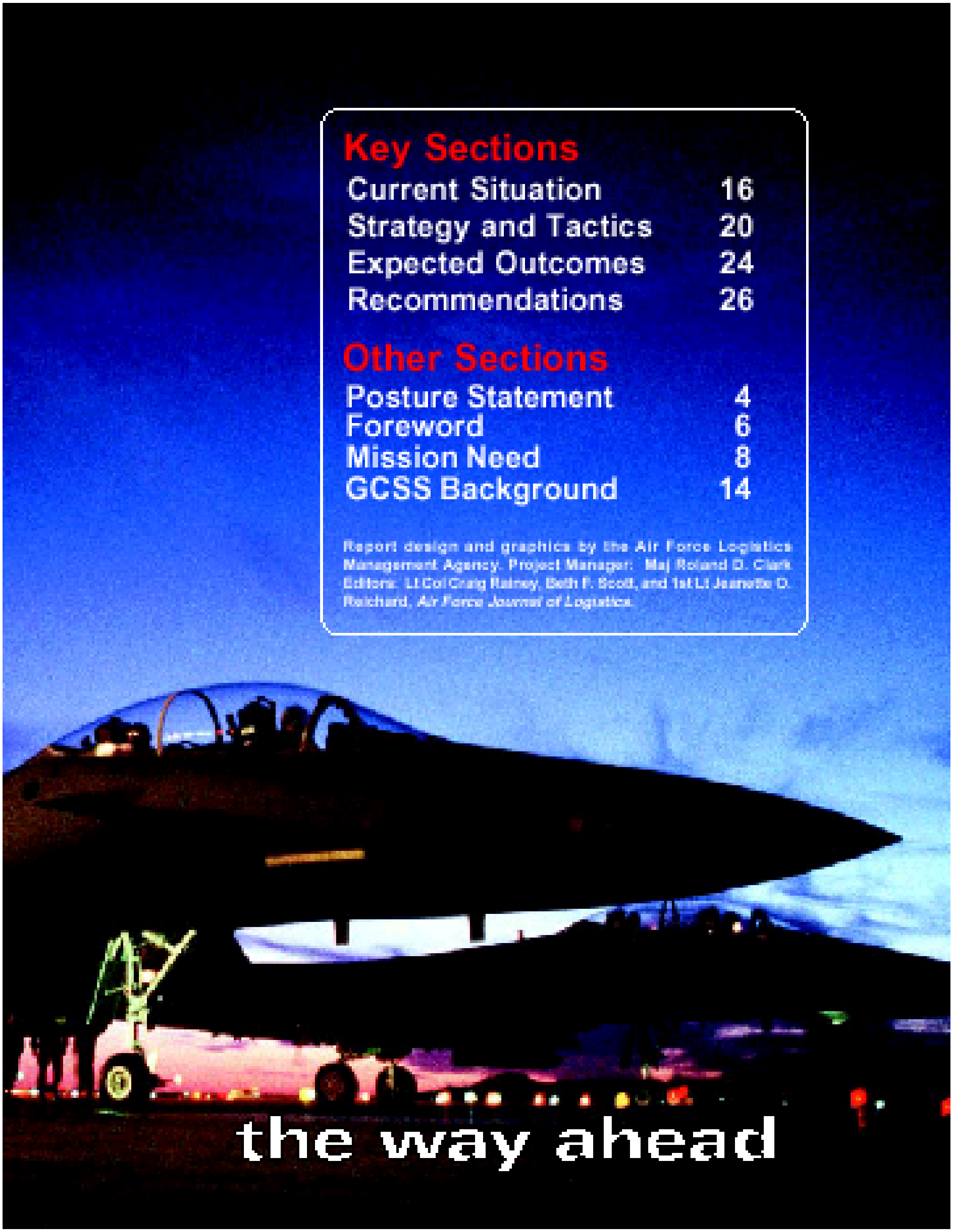
- **Security**: Improve system security to the extent possible to protect the system from deliberate attack and prevent unauthorized access to data and applications.
- **Testing**: Reduce testing costs because common software can be tested and validated once and then applied to many applications.

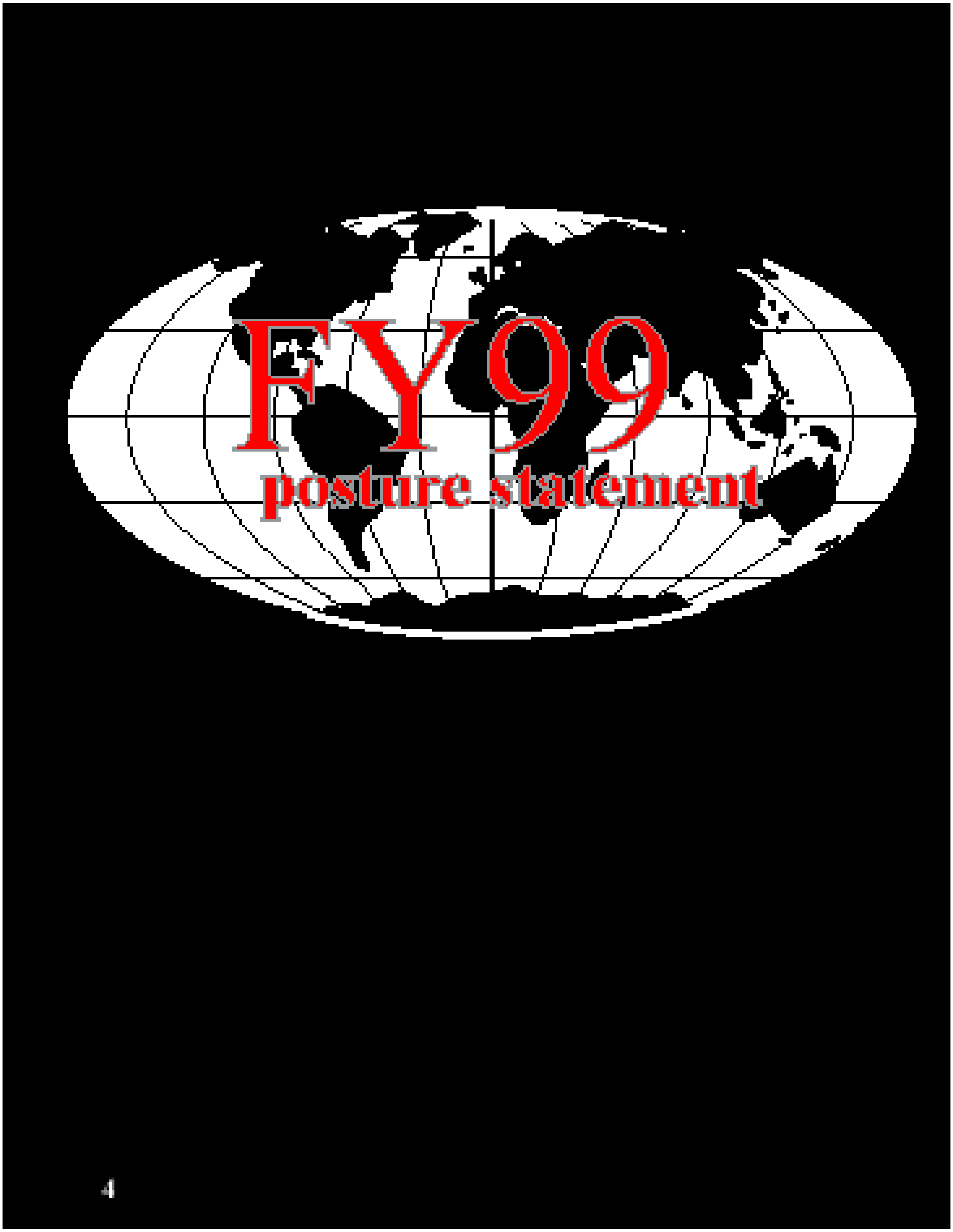
(This Page Intentionally Left Blank)

Appendix 6H
GCSS-AF The Way Ahead (Volume 1)




Vision
GCSS-AF
GCSS-AF will provide the warfighter and supporting elements with timely, accurate, and trusted Agile Combat Support information, with the appropriate level of security, needed for the Expeditionary Aerospace Force to execute the Air Force mission throughout the full spectrum of military operations.


Key Sections
Current Situation 16
Strategy and Tactics 20
Expected Outcomes 24
Recommendations 26
Other Sections
Posture Statement 4
Foreword 6
Mission Need 8
GCSS Background 14
Report design and graphics by the Air Force Logistics Management Agency. Project Manager: Maj Roland D. Clark
Editors: Lt Col Craig Rainey, Beth F. Scott, and 1st Lt Jeanette D. Reichard, Air Force Journal of Logistics.
the way ahead

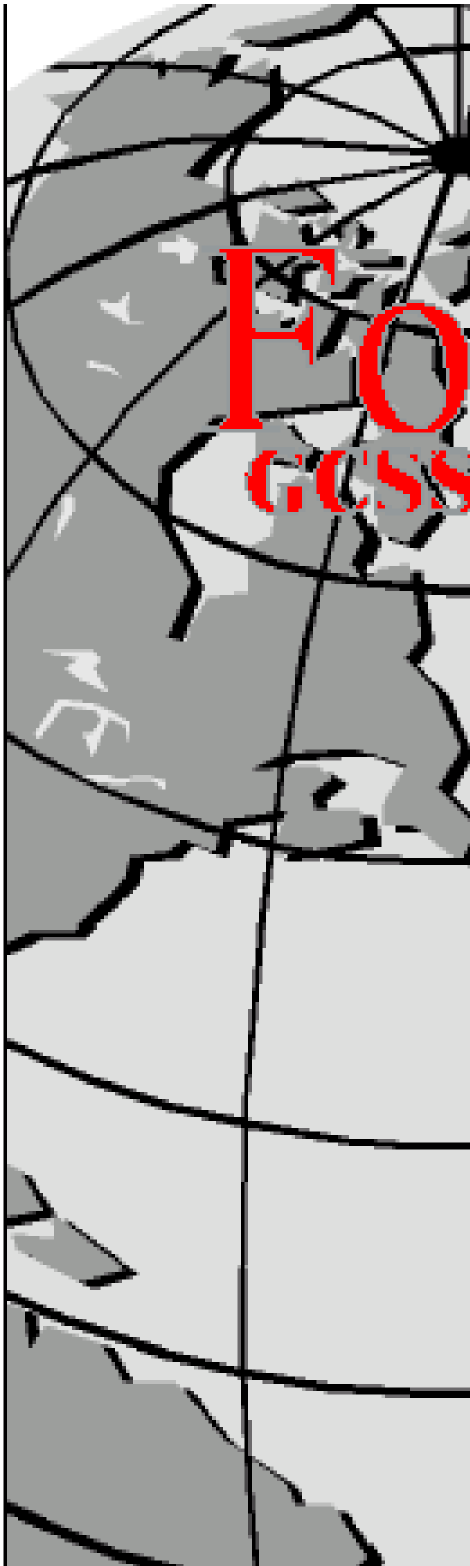

FY99
posture statement
4

. . . The success of the Expeditionary Aerospace Force ultimately will rest on the Air Force's ability to sustain it. Agile Combat Support provides commanders improved responsiveness, mobility, and sustainability of their forces . . . .

. . . Information technologies, such as the Global Combat Support System, featuring both new leading-edge capabilities and technical refreshment of existing systems, are key to Agile Combat Support . . . .

—General Michael E. Ryan
Chief of Staff, United States Air Force

—Honorable F. Whitten Peters
Secretary of the Air Force



Foreword

GCSS-AF

The time is right to implement the recommendations. The EAF concept depends on an integrated GCSS-AF. The Chief Information Officer can provide the appropriate impetus, and technology is now an enabler rather than a limiting factor.

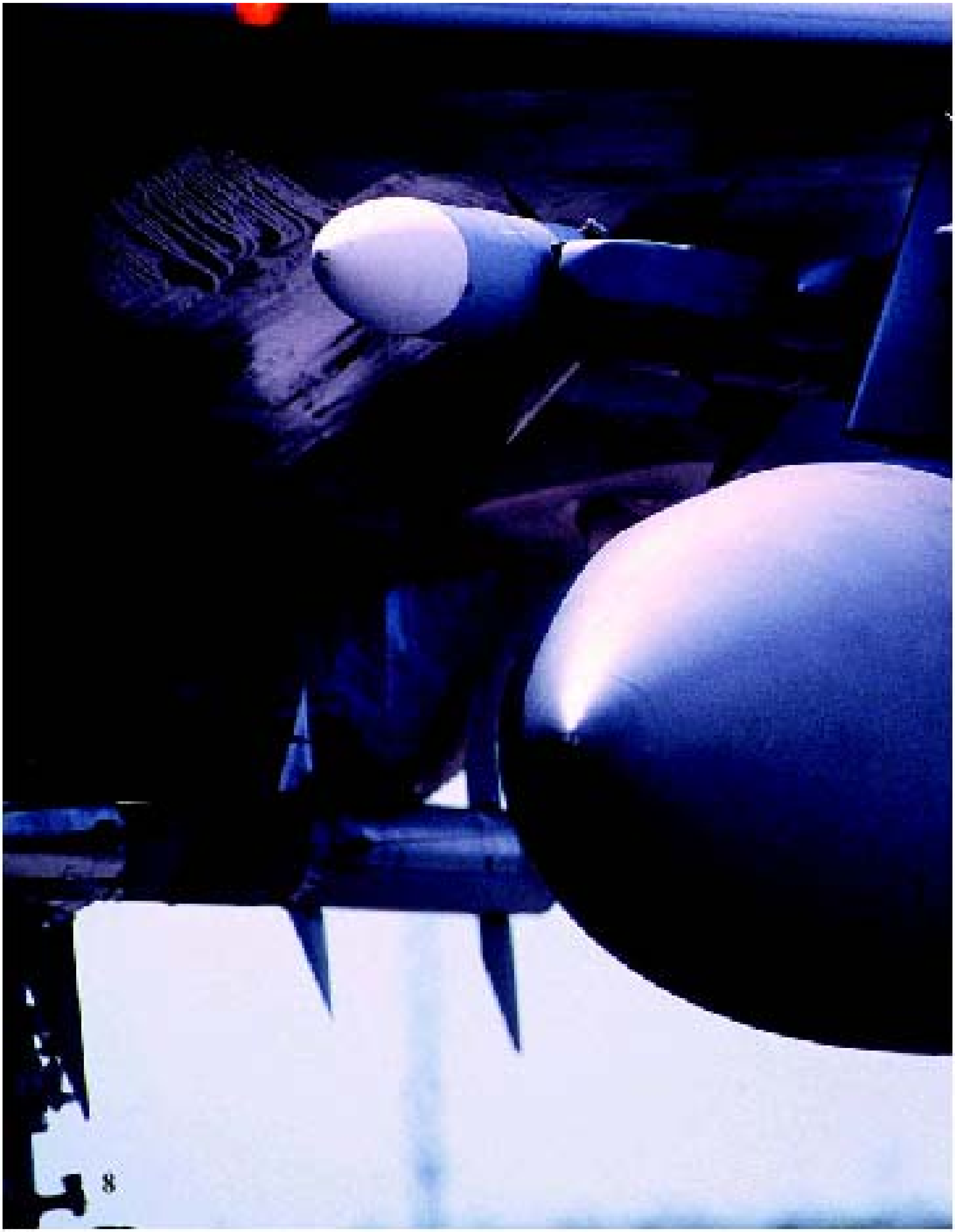
The Chief Information Officer (CIO) gave the Global Combat Support System-Air Force (GCSS-AF) Requirements Integration Tiger Team (GRITT) a tough, but important, task—develop an integrated requirements process that will ensure a strong and successful GCSS-AF. The task is tough because it requires agreement among various functional organizations to adopt an enterprise view of combat support information. The task is important because the Expeditionary Aerospace Force (EAF) concept relies on integrated systems that provide timely, accurate, and trusted information to the deployed Air Expeditionary Force (AEF) commander across the spectrum of military operations.

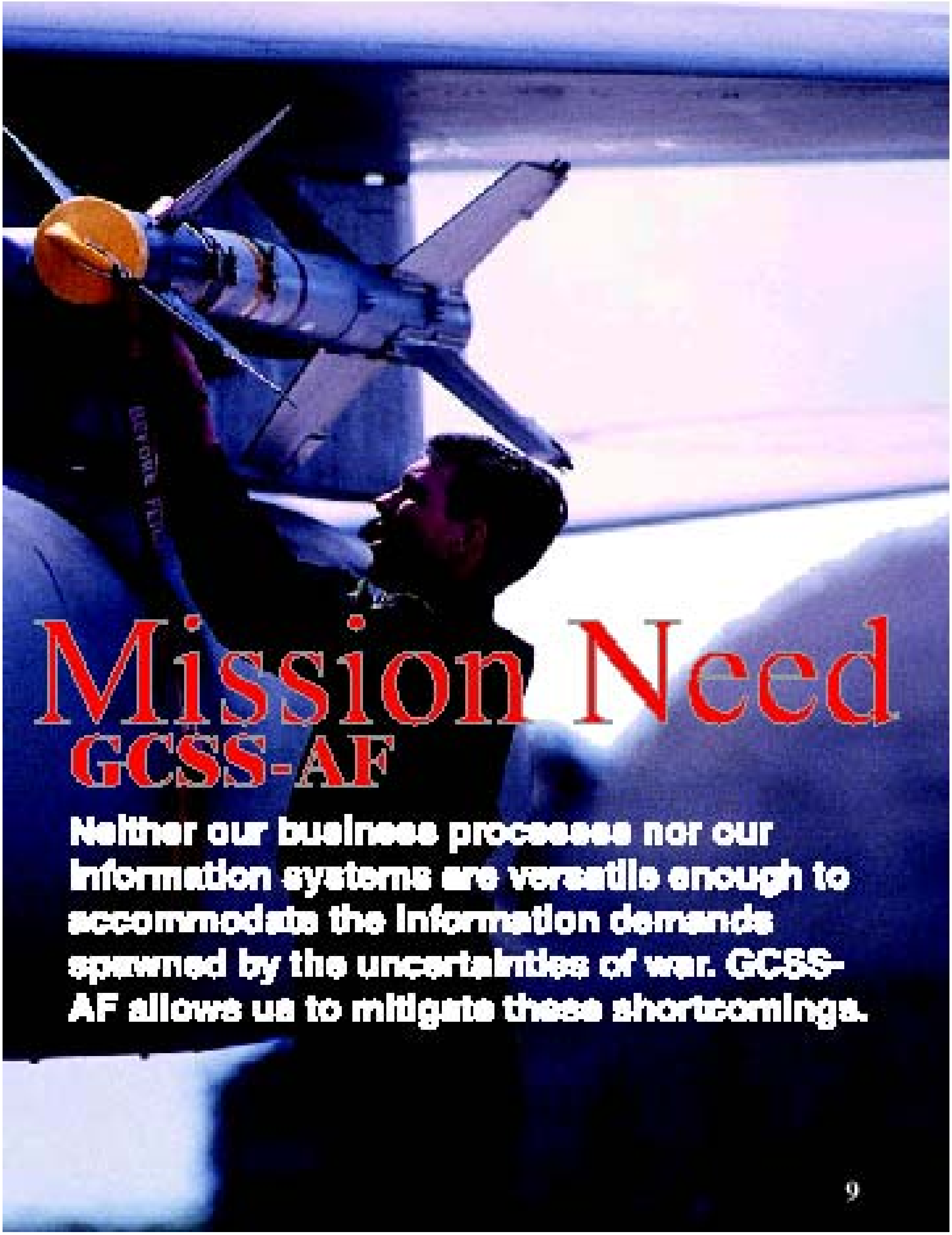
We worked the problem hard—dedicated subject matter experts pooled their collective experience to provide the recommendations in this report. Each contributed to the final product—each should be proud of that contribution.

The combat support process has evolved throughout the years with many functional organizations providing a piece of a very large enterprise. Functional communities are performing quality work to improve their processes and modernize their systems. While everyone supports the need for integrated information to support the warfighter, the different organizational alternatives were appealing in varying degrees to various agencies. It was impossible to build unanimous agreement for our recommendations—consensus was difficult but achievable.

We believe the time-phased approach recommended provides the best alternative for achieving the vision of a GCSS-AF capable of supporting EAF deployments and operations. In the near term, we believe a Director for GCSS-AF and EB/EC is required to begin implementation of the recommendations. Ultimately, we believe the Aerospace Command and Control Intelligence, Surveillance, and Reconnaissance Center (AC2ISRC) should lead this effort for our Air Force because of its warfighting focus, experience with experimentation, and the inevitable integration between the Global Command and Control System (GCCS) and GCSS. Our recommendation fully supports the Joint GCSS program and postures the Air Force to be a leader in combat support systems development.

—BUD BELL, Brig Gen, USAF
Chief, GCSS-AF Requirements
Integration Tiger Team (GRITT)

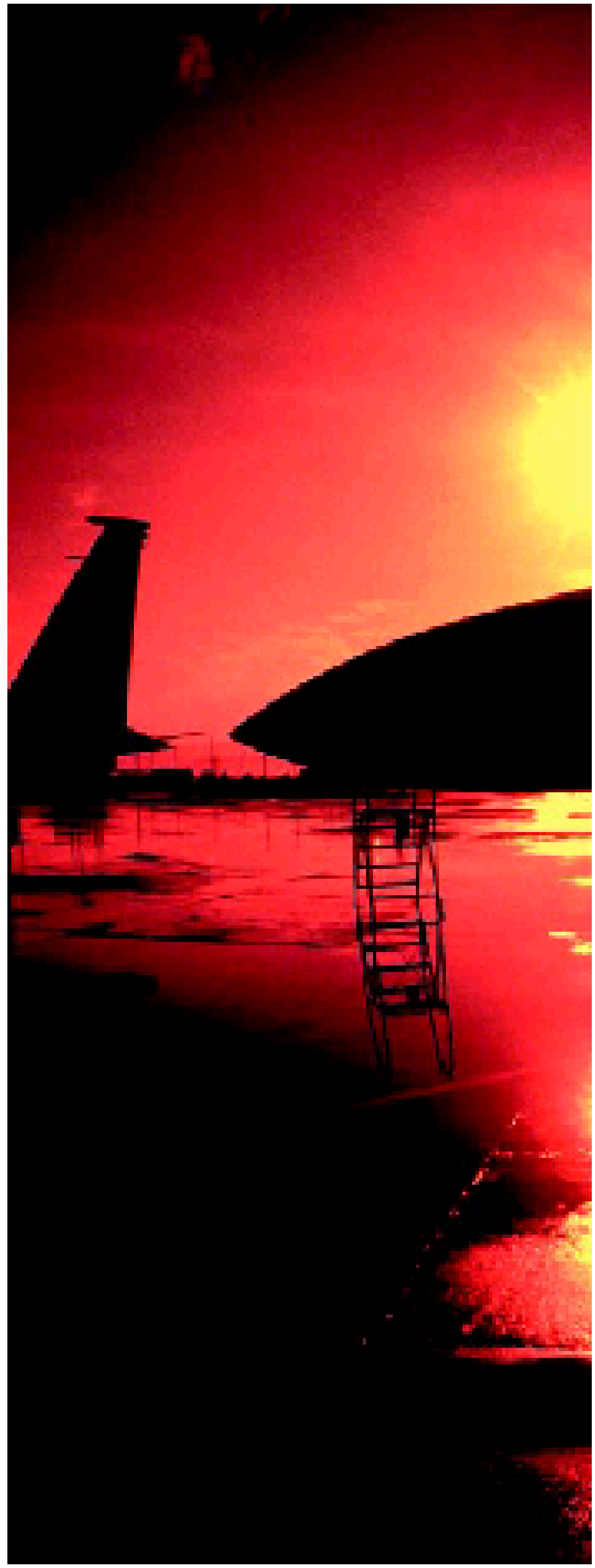

8

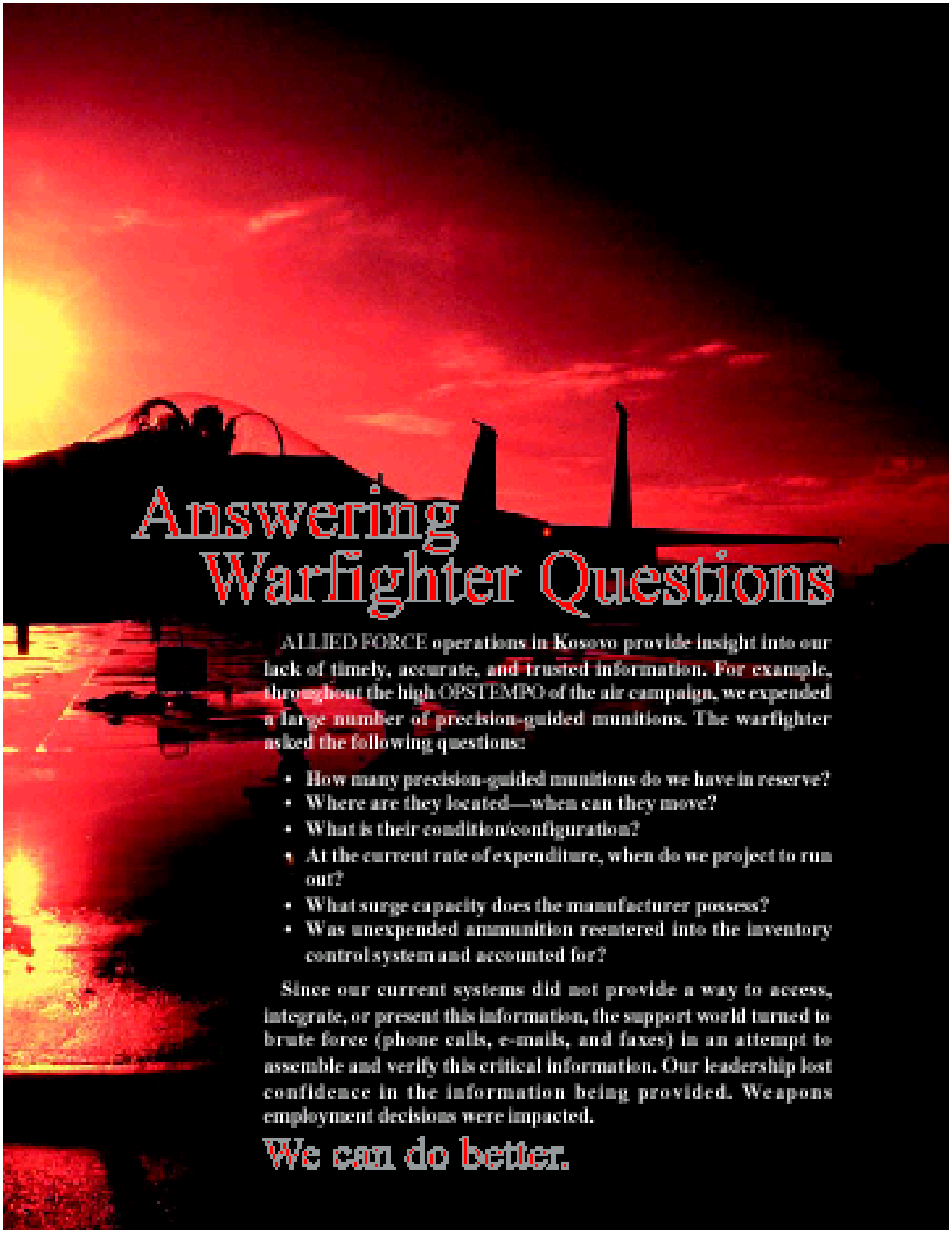

Mission Need
GCSS-AF
Neither our business processes nor our information systems are versatile enough to accommodate the information demands spawned by the uncertainties of war. GCSS-AF allows us to mitigate these shortcomings.
9

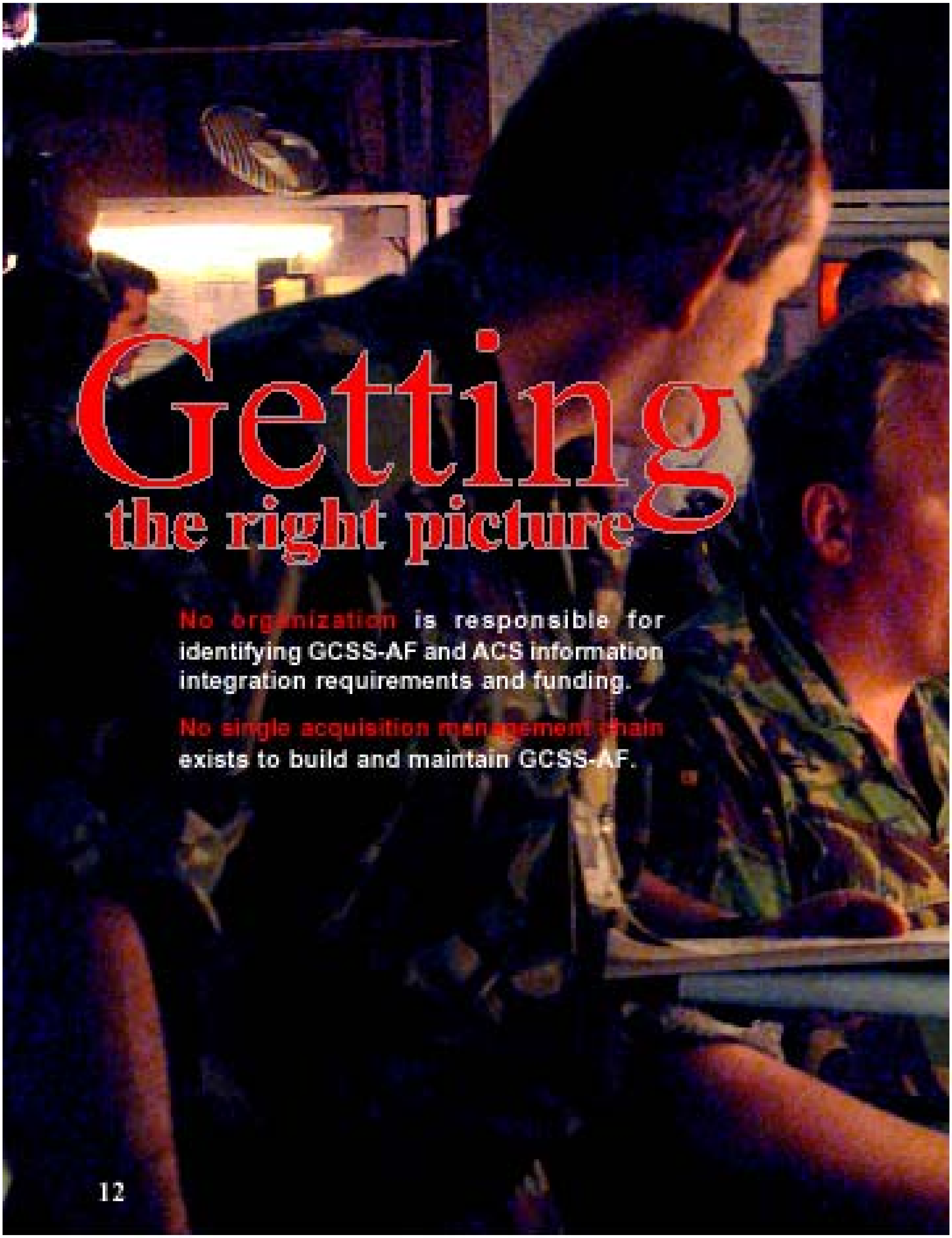
The Air Force warfighter must be able to communicate and assimilate information rapidly. This information must be timely, accurate, and trusted to enable commanders to shape and define the battle space with confidence. The warfighting commanders must have real-time visibility of relevant Agile Combat Support (ACS) information for both in-garrison and deployed forces, assisting them to perform their operational mission at any location on or above the globe. The information must also meet the needs of the Secretariat, Air Force functional areas, and commanders at all levels while enhancing their leadership role.

A properly designed GCSS-AF system will provide information that is timely, accurate, and trusted.

The current systems developed for the Cold War inhibit successful AEF operations. The current information processes supported by these systems are too complex, fragmented, and slow to meet warfighter needs effectively and efficiently. We need to improve how we generate, maintain, share, portray, and use data. For each item of data that is captured, there must be a single authoritative source for use by both functional and warfighter processes. To meet the vision, effective processes must be implemented and technological advances incorporated into our current systems.




Answering
Warfighter Questions
ALLIED FORCE operations in Kosovo provide insight into our lack of timely, accurate, and trusted information. For example, throughout the high OPSTEMPO of the air campaign, we expended a large number of precision-guided munitions. The warfighter asked the following questions:
• How many precision-guided munitions do we have in reserve?
• Where are they located—when can they move?
• What is their condition/configuration?
• At the current rate of expenditure, when do we project to run out?
• What surge capacity does the manufacturer possess?
• Was unexpended ammunition reentered into the inventory control system and accounted for?
Since our current systems did not provide a way to access, integrate, or present this information, the support world turned to brute force (phone calls, e-mails, and faxes) in an attempt to assemble and verify this critical information. Our leadership lost confidence in the information being provided. Weapons employment decisions were impacted.
We can do better.


Getting
the right picture
No organization is responsible for identifying GCSS-AF and ACS information integration requirements and funding.
No single acquisition management chain exists to build and maintain GCSS-AF.
12


13

GCSS background

GCSS-AF grew out of earlier Air Force system development efforts. In 1995, the Air Force Materiel Command (AFMC) was tasked to modernize base-level information systems. In that same year, under the Base-Level Systems Modernization (BLSM) program, the Air Force Mission Support Command, Control, Communications, Computer, and Intelligence (C4I) Architecture Council identified technical interoperability requirements but lacked funding for implementation.

In 1996, BLSM was renamed GCSS-AF to be consistent with direction from the Office of the Secretary of Defense (OSD). In March, the Air Force officially established the GCSS-AF System Program Office (SPO) at Electronic Systems Center's (ESC) Standard Systems Group (SSG). The Air Force Directorate of Communications and Information (AF/SC) became the lead for GCSS-AF. The GCSS-AF contract was awarded in December 1996 to Lockheed Martin Federal Systems. When the Joint Chiefs of Staff J4 was designated as the GCSS functional proponent, the Chief of Staff of the Air Force (CSAF) named the Deputy Chief of Staff, Installations and Logistics (AF/IL) the functional proponent for GCSS-AF.

In July 1997, AF/IL established the GCSS-AF Coordinating Council, a general officer group with cross-functional representation, to identify and manage combat support information requirements. The Council was later renamed the GCSS-AF Board of Directors, but it lacked the responsibility, authority, and resources to effect a successful strategic path to GCSS-AF. In September 1997, ESC reorganized and disbanded the GCSS-AF SPO, establishing SPOs aligned with functional areas, and charging them to maintain and modernize systems. At this point, GCSS-AF became a concept and strategy rather than a program. The SSG Infrastructure Division (HQ SSG/DII) was tasked to develop and acquire a commercial off-the-shelf, defense information infrastructure common-operating-environment GCSS-AF integration framework.

Acquisition oversight of information system programs was split between an Air Force program executive officer (PEO) for logistics systems and the designated acquisition commander for most of the remaining systems. In addition, some systems were developed and maintained outside the standard Air Force acquisition chain.

No single organization is the lead agency to identify cross-functional requirements. This problem was addressed in 1997 when the draft charter for the AC2ISRC included the responsibility for ACS information system requirements. However, in the coordination process to finalize the charter, this responsibility was deleted.

No single organization is the lead agency to identify cross-functional requirements.

On 7 May 1999, the Air Force Chief Information Officer Management Board (CIOMB) established the GRITT to ". . . develop a game plan for pulling together the requirements and strategy for achieving a strong and successful GCSS-AF, electronic business and electronic commerce effort." As a result, the GRITT proposes a strategy to identify a combat support champion with the authority, responsibility, and resources to deliver an integrated GCSS-AF that supports Agile Combat Support—an essential element of the Expeditionary Aerospace Force.

In support of this effort, the GRITT:

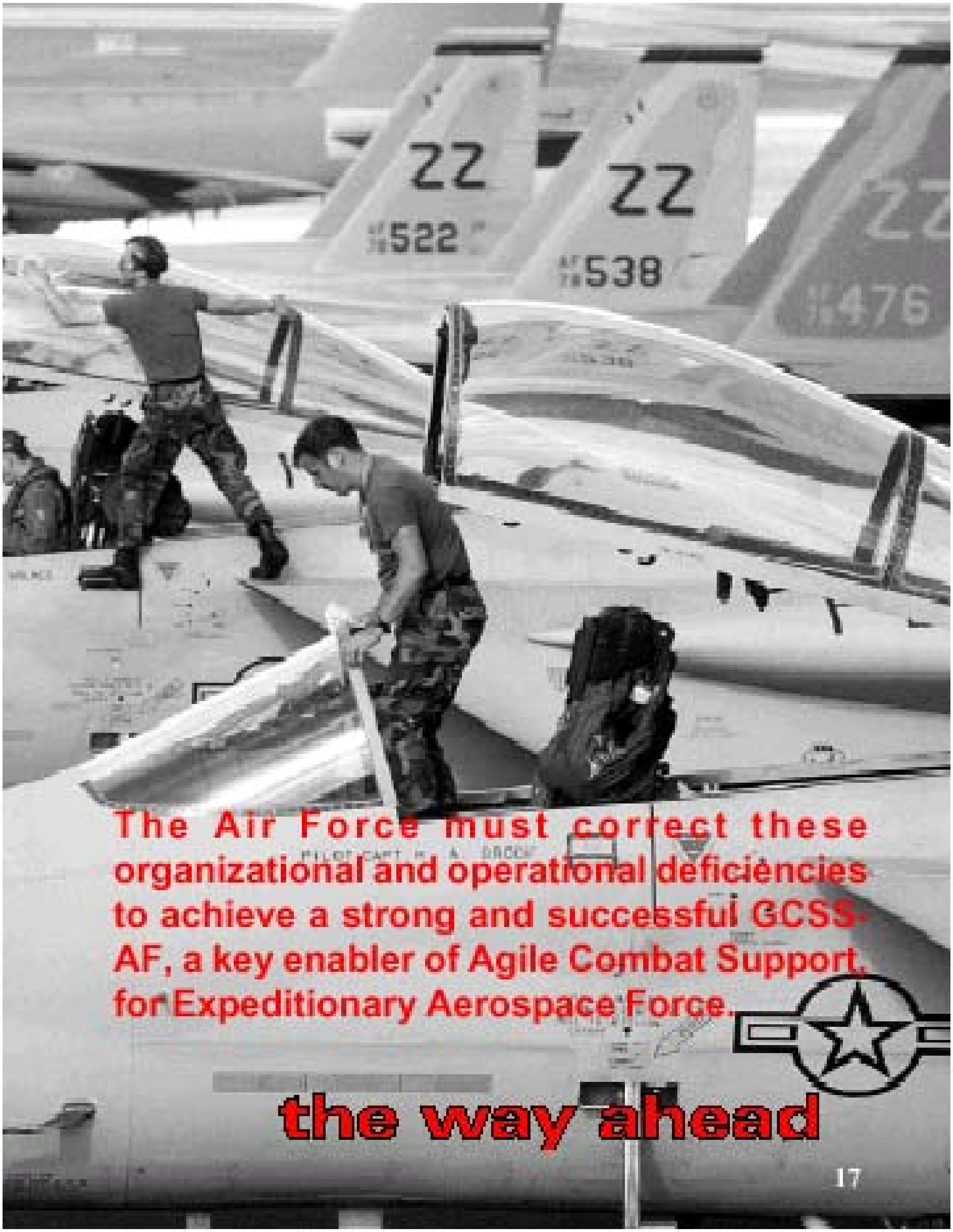
- Developed a proposal on how to organize and proceed to define GCSS-AF requirements, achieve process reengineering, fund and implement GCSS-AF and Electronic Business/Electronic Commerce (EB/EC).
- Addressed organizational structure, location, and size.
- Identified a lead agency to champion GCSS-AF integration activities.
- Drafted a lead agency charter defining responsibilities.
- Developed the business case to support the recommendations in this report.
- Drafted an operational requirements document (ORD) and a program management directive (PMD).

The team was also tasked to obtain Secretary of the Air Force/CSAF approval on the proposal.

GRITT
taskings

15


Current
situation
• No GCSS-AF unified vision.
• No requirements lead agency.
• No single acquisition management chain.
• No warfighter confidence in information supplied.
• No EB/EC single manager.
16


The Air Force must correct these organizational and operational deficiencies to achieve a strong and successful GCSS-AF, a key enabler of Agile Combat Support, for Expeditionary Aerospace Force.
the way ahead
17

Changing landscape

What has changed?

Expeditionary Aerospace Force

The Expeditionary Aerospace Force is the Air Force vision to organize, train, equip, and sustain itself to provide rapidly responsive tailored aerospace forces for 21st century military operations. Air Expeditionary Forces are required to deploy anywhere in the world and put bombs on target within 48 hours. Modern integrated information systems delivered by GCSS-AF are essential to support the light, lean, and lethal force packages of the Air Expeditionary Force.

Information Technology Management Reform Act (ITMRA)

The ITMRA, effective 8 August 1996, created CIOs charged to develop, maintain, and facilitate the implementation of a sound and integrated information architecture. It also requires the refinement of business processes before investing in information technology. The CIOMB has matured and is ready to act.

Technology

New technologies allow us to share information in a networked, distributed, and collaborative environment. We are just beginning to realize the operational utility this capability provides. At the same time, we are now faced with a new set of technological challenges, in particular, information assurance.

Spiral Development, Modeling and Simulation, and Experimentation

Spiral development, modeling and simulation, and experimentation such as the Joint Expeditionary Force eXperiment (JEFX) mitigate development risks associated with rapidly changing information technology by enabling us to identify and correct deficiencies prior to fielding. Strong user participation during experimentation and spiral development ensures systems satisfy the operational requirement.

Economy and Personnel Realities

We are now faced with multiple divergent trends: end strength, experience levels, and retention rates have decreased while our OPSTEMPO has increased. We must find ways to use technology to operate more efficiently and effectively while supporting numerous and increasingly complex missions.

While both the Secretary and Chief of Staff of the Air Force have stated GCSS-AF is a key ACS enabler, critical to EAF success, the Air Force has neither a stable, unified vision of GCSS-AF nor a champion to advocate the vision.

Limiting Factors

A number of limiting factors prevent the Air Force from realizing a strong and successful GCSS-AF to effectively support the Air Expeditionary Force.

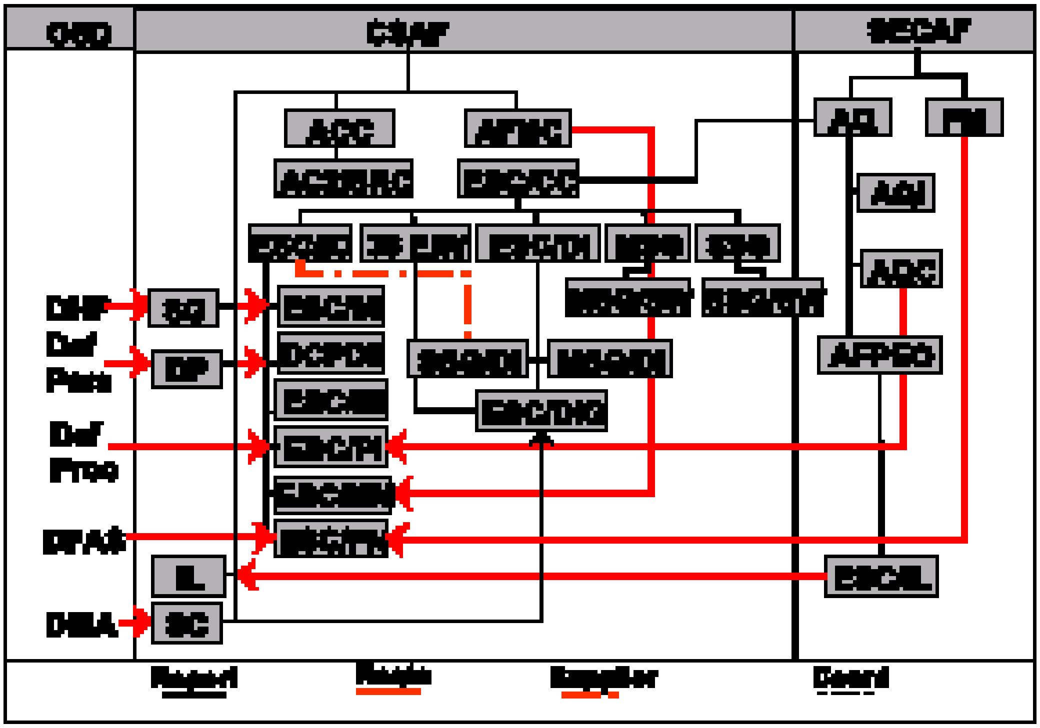
No GCSS-AF Unified Vision

While both the Secretary and Chief of Staff of the Air Force have stated GCSS-AF is a key ACS enabler, critical to EAF success, the Air Force has neither a stable, unified vision of GCSS-AF nor a champion to advocate the vision.

No Requirements Lead Agency

Current functionally aligned information systems support combat operations and legacy business practices. However, no organization focuses on cross-functional combat support information requirements or process integration and improvement initiatives.

In addition, no organization advocates integration requirements through the corporate process. Functional process owners invest in functional system capabilities rather than cross-functional integration. SPOs receive conflicting guidance relating to integration requirements. Developments tasked independently to satisfy specific functional requirements encourage the development of separate, unintegrated systems. As a



GCSS-AF Organizations and Relationships

result, insufficient funding is committed for integrated ACS information systems needed to support the Expeditionary Aerospace Force.

No Single Acquisition Management Chain

GCSS-AF acquisition management is undertaken by both a program executive officer and a designated acquisition commander. Thus, the Air Force does not have an official below the Assistant Secretary of the Air Force (Acquisition) responsible for implementing GCSS-AF. There are also programs not under these acquisition management structures that have no mandate to integrate into GCSS-AF or interoperate with other combat support applications. As a result, there is potential to implement conflicting or multiple solutions to common problems. Additionally, funding conflicts may occur which would be resolved best by a single acquisition chain.

No Warfighter Confidence in Information Supplied.

Because the information supplied is not timely, accurate, or trusted, the warfighter seeks alternative, manual information verification. These alternative processes waste time and, in the worst possible scenarios, may result in failed missions or loss of life. Confidence in our combat support information is critical to the success of our warfighting processes.

A number of information assurance issues may inhibit achieving a strong and successful GCSS-AF, specifically:

- Protection of aggregated data.
- Defense against network *denial-of-service* attacks.
- Implementation of multi-level security capability.

No EB/EC Single Manager

EB/EC describes the use of commercial standards, practices, and business process improvement techniques to conduct business by an electronic means within or outside of an organization. Combat support information systems undertake EB/EC today, and the lead agency's role will promote further use of EB/EC within GCSS-AF. However, Air Force information systems other than GCSS-AF also use EB/EC techniques.

Currently, there is no coordinated Air Force plan to use EB/EC techniques consistently to enable Agile Combat Support. Like GCSS-AF, there is no dedicated Air Force organization to develop and coordinate EB/EC policy and requirements. The relationship between GCSS-AF and EB/EC is so close that their respective policies should be inextricably linked.


EG
Strategy
and tactics
• Recognize, understand, and accept one GCSS-AF vision across the Air Force.
• Create a requirements lead agency.
• Streamline GCSS-AF application and integration acquisition management.
• Improve warfighter confidence in combat support information.
• Consolidate EB/EC management under GCSS-AF.
• Develop and use key measures and metrics.
20


the way ahead
21

Recognize, understand, and accept one GCSS-AF vision across the Air Force. Embrace and institutionalize GCSS-AF.

The GCSS-AF vision is to provide the warfighter and supporting elements with timely, accurate, and trusted ACS information, with the appropriate level of security, needed for the Expeditionary Aerospace Force to execute the Air Force mission throughout the full spectrum of military operations.

The warfighter needs to be able to communicate and rapidly assimilate accurate and timely information that will be used to shape and define the battle space. *Blue Order of Battle* information from combat support information systems must be available in near real-time for missions at any location in the world. GCSS-AF information must also continue to meet the functional needs of the Secretariat, Air Staff functional areas, and commanders at all levels.

A champion is needed to advocate the GCSS-AF vision. The champion must ensure the need for GCSS-AF and its vision are understood.

Create a requirements lead agency to focus on combat support integration requirements of the warfighter needed to implement the Expeditionary Aerospace Force, consistent with JV2010 and Air Force Global Engagement.

Composed of functional area representatives and experts, the lead agency will:

- Develop/control/manage GCSS-AF warfighter and combat support information integration requirements
- Identify candidate processes for business process reengineering and improvement or reuse of existing software
- Staff and advocate an integrated GCSS-AF program objective memorandum (POM) input.
- Control integration funding.
- Coordinate and interface with the Joint Staff.
- Drive GCSS-AF involvement in JEFX and J4 ACS experiments.
- Harmonize EB/EC implementation issues.

Four main options for lead agency were evaluated:

- Expand AFMC.
- Create a direct reporting unit reporting to the Deputy Chief of Staff for Plans and Operations.
- Create a direct reporting unit reporting to AF-CIO.
- Expand AC2ISRC.

Each option was considered capable of accomplishing the lead agency tasks given the appropriate authority, responsibility, and resources.

Expanding the AC2ISRC at Langley AFB was selected as the strongest option because it:

- Maintains the warfighter focus.
- Is in a position to view the spectrum of combat support requirements in relation to the GCCS and Intelligence, Surveillance, and Reconnaissance (ISR).
- Has close ties to JEFX and J4 ACS experiments.
- Manages the integrated POM for GCCS and ISR.

Expanding the AC2ISRC at Langley AFB was selected as the strongest option.

To allow AC2ISRC adequate ramp-up time, an interim organization with a limited set of tasks should be created. This interim organization of 13 to 15 functional and technical representatives will be headed by a general officer/Senior Executive Service (GO/SES) Director for GCSS-AF and EB/EC.

Functional communities will:

- Participate in GCSS-AF integration efforts.
- Control functional business processes.
- Identify functional requirements.
- Manage funding of legacy systems maintenance and modernization.
- Improve business processes.

Streamline GCSS-AF application and integration acquisition management.

The GCSS-AF acquisition community should adopt a single acquisition management chain responsible for satisfying all combat support application and integration requirements. Combat support programs outside the acquisition chain of command will need to be integrated into GCSS-AF without reducing the flexibility and innovation available through existing distributed execution.

The single acquisition management chain would execute both functional requirements funded by the functional communities and integration requirements funded by the lead agency. The Mission Area Director will work with the PEO and system program directors to ensure enterprise and functional information requirements are met.

A GCSS-AF SPO should be established to develop the integration framework and enterprise-level applications and provide guidance to functional application developers in creating GCSS-AF compliant integrated applications.

Because GCSS-AF will be an Acquisition Category I program and an OSD and Joint interest program, the recommended solution is a PEO structure.

Improve warfighter confidence in combat support information.

The warfighter must be able to trust and have confidence in the information used to make decisions. Continued modernization of functional systems, together with implementation of GCSS-AF, is designed to improve information quality and warfighter confidence.

The GCSS-AF integration framework provides common user services such as data sharing capabilities, public key infrastructure digital signature for user identification, data encryption, and role-based access control. Global Grid will provide a robust network for the sharing of timely, accurate, and trusted information.

The lead agency will orchestrate functional and ESC efforts to develop a corporate solution for storing and transmitting combat support information. In concert with the Joint Technical Architecture-Air Force, ESC and AF/SC must continue to address the issues of denial of service attacks and multi-level security.

Consolidate EB/EC management under GCSS-AF.

Without consolidated Air Force EB/EC leadership, there will be conflicting lines of responsibility and authority, leading to different EB/EC implementations across GCSS-AF systems.

The lead agency will ensure EB/EC policy is correctly implemented within GCSS-AF and identify and advocate funding for existing and prototype EB/EC initiatives. Developers of functional applications must ensure EB/EC implementations are consistent with the technical guidance provided by OSD, ESC, and the Air Force Communications Agency.

GCSS-AF and EB/EC strategies and road maps must be linked to the current Air Force Modernization Planning Process, Air Force Strategic Plan, and Department of Defense guidance. This will ensure they are integrated into Air Force combat support processes and that effective modernization strategies and investment plans are developed. Air Force EB/EC policy will be developed by the proposed interim Director for GCSS-AF and EB/EC organization; this responsibility will remain at the Pentagon when the lead agency migrates to the AC2ISRC.

Develop and use key measures and metrics to sustain the GCSS-AF effort.

The combat support definitions contained in the draft *Joint Capstone Requirements Document* for GCSS will be vital to the metrics development process. Targets expressed in the capstone requirements document also provide information for use in metrics definition. GCSS metrics should evolve over time, account for the incremental development of GCSS, and be concise and cost-effective to collect and use. Preliminary metric inputs have been captured in the full report and the GCSS-AF ORD. Metrics development should focus on process outcomes and contain some subjective measures such as stakeholder satisfaction or attainment of vision.

Recognize, understand, and accept one GCSS-AF vision across the Air Force. Embrace and institutionalize GCSS-AF.

Create a requirements lead agency to focus on combat support integration requirements of the warfighter needed to implement the Expeditionary Air Force, consistent with JV2010 and Air Force Global Engagement.

Streamline GCSS-AF application and integration acquisition management.

Improve warfighter confidence in combat support information.

Consolidate EB/EC management under GCSS-AF.

Develop and use key measures and metrics to sustain the GCSS-AF effort.

The Way Ahead

Expected outcomes

The case for GCSS-AF is more operational than financial. GCSS-AF in an essential enabler for ACS—a key to EAF success. Initial return-on-investment analysis suggests only small quantifiable financial savings might be achieved across combat support. However, GCSS-AF brings significant improvements essential to meet the needs of the warfighter. These would be more difficult, if not impossible, to achieve without GCSS-AF.

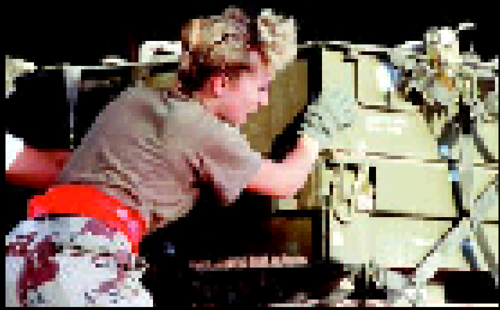
the way ahead

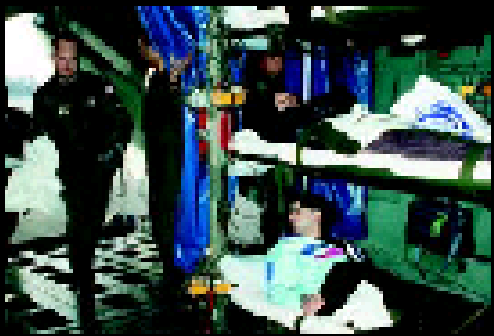
With a Long-Term Commitment to GCSS-AF, the Air Force would achieve:

- A world-class combat support information system capable of contributing to Information Superiority, Rapid Global Mobility, and Agile Combat Support.
  - Smaller deployed footprint.
  - Fewer resources employed.
  - More agile forces.
  - Fewer personnel deployed.
- Timely, accurate, and trusted information for the warfighter and functional user.
  - Better and faster decisions.
  - Faster execution of warfighter direction.
- A consolidated approach to EB/EC and GCSS-AF.
- Less training due to intuitive user interface and common look and feel.
- Improved security and reliability of our combat support information systems.
- Business process improvement/reengineering consistent with modern, evolving practices.
- Access to integrated cross-functional information from a single input.
- A GCSS-AF lead agent with the authority, responsibility, and resources needed to direct and manage information system integration.
- A consistent approach to providing the timely, accurate, and trusted information required for the Expeditionary Aerospace Force.

Integration Cost Benefit

By late August 1999, the responsible SPO expects to complete a thorough study of the costs of integrating 135 logistics systems into the GCSS-AF integration framework. Preliminary results indicate that 35 of the 135 applications are expected to be eliminated through consolidation of duplicate functions. This is estimated to save an average of $12M a year when fully implemented in FY05. Extrapolating the forecast logistics systems savings to all combat support systems, annual potential savings of $22M might be expected. Achieving these savings requires an investment of approximately $15.9M a year. Further, based upon the expert opinion of the ESC Information Programs Officer, the integration framework needed to support the Expeditionary Aerospace Force requires an additional $8M a year through FY05. These figures support the view that the financial cost benefit is broadly neutral in the long term.





AC2ISRC Operations

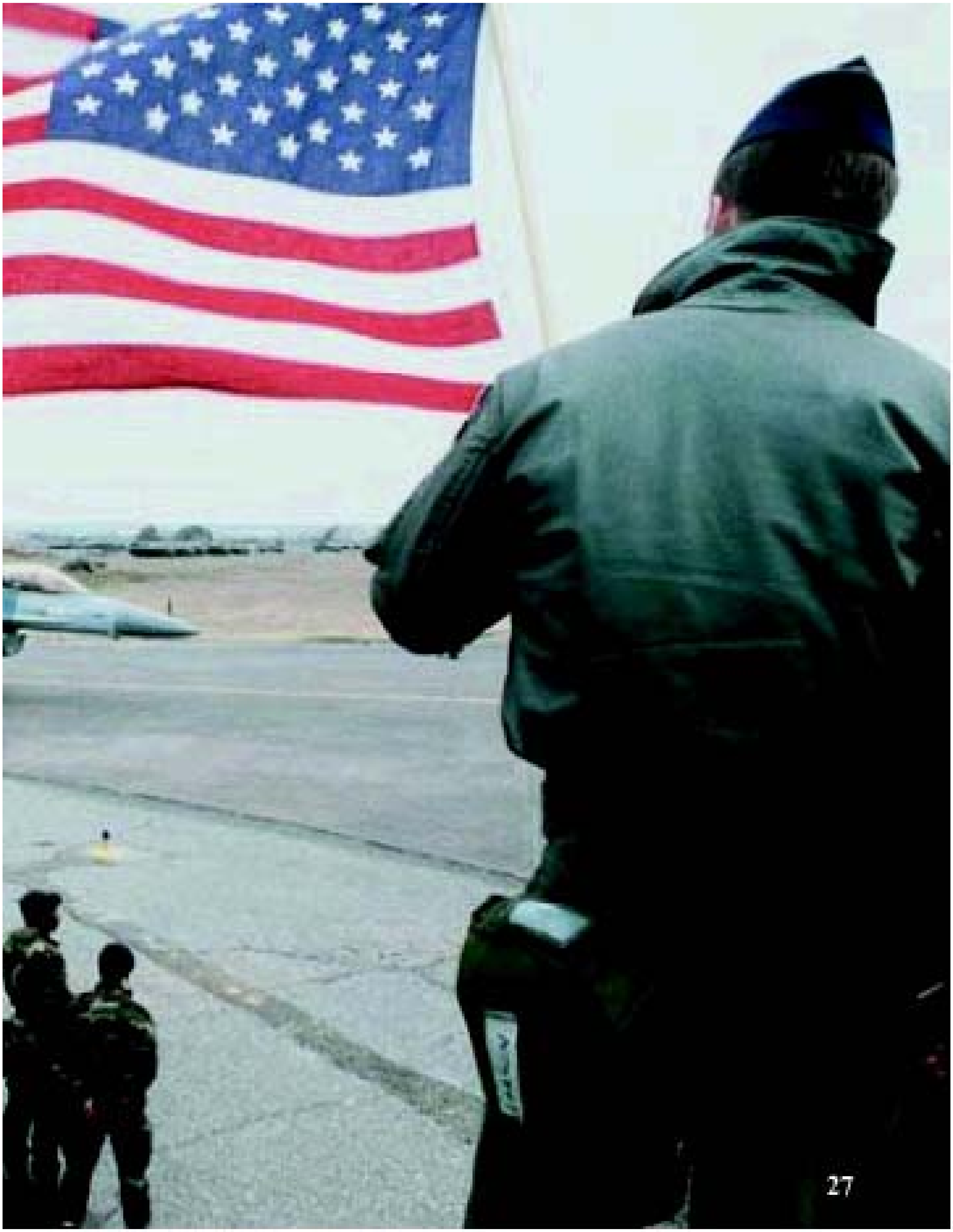
The stand-up of the GCSS-AF lead agency at the AC2ISRC will require sufficient resources. A GO/SES and 30 people are needed to perform the mission. An operating budget of $3M a year is required and includes contractor support personnel plus operating costs (TDY, supplies, etc.) for the AC2ISRC GCSS-AF directorate.

25

Recommendations

To achieve a strong and successful GCSS-AF, the GRITT makes the following recommendations:

- Designate a champion for GCSS-AF.
  - Designate a GO/SES-level Director for GCSS-AF and ED/EC with a transition team of 13 to 15 people to act as interim lead agency until transition to the AC2ISRC.
  - Designate the AC2ISRC as the permanent lead agency starting 1 January 2001, or sooner if• possible, and collocate the lead agency staff with the Center.
- Coordinate and approve the lead agency charter amendment, which will include responsibility for:
  - The requirements integration process.
  - The classification authority for aggregated data.
  - The integrated POM strategy.
  - Coordinating a GCSS-AF ORD.
- Approve resources for the lead agency beginning in FY01 for approximately 30 people, $3M a year operating costs, and $24M a year for the GCSS-AF integration framework and integration of applications into GCSS-AF.
- Establish a single acquisition management organization responsible for implementing GCSS-AF requirements. It is recommended that they:
  - Approve the PMD.
  - Establish a GCSS-AF SPO.
- CSAF sign a message directing assistance in completing the tasks outlined in the lead agency charter.
- Direct that all Air Force combat support systems integrate into GCSS-AF and comply with its standards.


27

From the GRITT Senior Advisory Group

We must plan and execute our deployment activities faster and more accurately than we do today if we're to effectively put bombs on target within 48 hours. Current planning processes do not adequately support employment of the Expeditionary Aerospace Force's (EAF) primary force element, the Air Expeditionary Force (AEF). We need tools to support rapid AEF employment with reduced deployment footprint. This will enable us to carry more *teeth* to the fight and, thus, increase our *tooth-to-tail* ratio.

Although our forces and support elements performed superbly in Kosovo, we relied too much on brute force, long hours over the telephone, and our high-quality people. As we become leaner and face new and different challenges, we must achieve new levels of integrated capability. We need to effectively employ new technologies being exploited today in the commercial sector—such as smart cards; web-browser-enabled business processes providing real-time updates of support status, from ammunition balances to individual shot record statuses; and integrated views of information across our functional communities—to free our personnel to carry the fight to our adversaries rather than staff phone banks to collect support status.

GCSS-AF, as a system of systems, is the principal tool that will deliver Agile Combat Support to the AEF. If the Air Force is to achieve the EAF vision, then the leadership must stand strong behind the GCSS-AF program, focus the functional communities on the mission value, and effectively implement the recommendations of the GRITT.

Gordon E. Fornell
Dayton Aerospace, Inc.

Harold W. Sorenson
The MITRE Corporation

John Foreman
Software Engineering Institute

Bob Majors
Independent Consultant

Appendix 6I
GCSS Capstone Test and Evaluation Master Plan (TEMP)

(See PDF File)

(This Page Intentionally Left Blank)

Appendix 6J
DODIIS Test Process

Explanation of Department of Defense Intelligence Information System (DODIIS) test process:

The DODIIS test process is an iterative process that follows the software item through its life cycle and assesses items continuous improvement towards meeting installation and integration requirements. The DODIIS testing team evaluates the testing requirements for each new software release early in the development cycle. The DODIIS development and testing process is detailed in the DODIIS Instructions document, which relates the process to DoDD 5000 series acquisition milestones.

DODIIS software products strive for one major release and one minor release yearly. Major releases generally add new functionality or interfaces or make other large scale changes to the software. Minor releases upgrade COTS or GOTS components and/or provide limited enhancements. Software "patches" are generally minor changes to provide corrections in response to user software problem reports and do not have to be tested under the DODIIS process.

The development program office is responsible for certifying Factory Acceptance Testing (FAT) has occurred and all documentation and other deliverables are acceptable. The FAT often involves a sampling of operational users.

The Joint Test Planning Meeting (JTPM) brings together all players (integration testers, security certifiers, interoperability testers (JITC)) to plan specific testing activities for a new software release as well as the resource requirements.

During Beta I testing the item is brought into an independent Government facility and turned over to the DODIIS testers. DODIIS testers check the ability to install and integrate the software into the DODIIS infrastructure (i.e., integration with COE environment). Security certification generally occurs at the Beta I test.

Beta II testing is typically conducted at an operational site. The JITC generally conducts interoperability testing (testing of interfaces for passing data between systems) at the Beta II site unless the interfaces and data are available at the Beta I government facility.

Training certification occurs in parallel to this process by the cognizant training organization.

The results of FAT, Beta I and Beta II tests are collated within 5 business days and attached to an Acquisition Decision Memorandum (ADM) prepared by the SPO. Specific recommendations are made relative to deploy/fix before deployment/fix and retest. The ADM is submitted the DODIIS Management Board (DMB). DMB is chaired by DIA and consists of voting members from each Service, the Unified Commands and other DoD IC Combat Support Agencies (NSA, NIMA, NRO). DMB makes a decision relative to deployment or other action.

DODIIS relative to OT&E:

There is NO conflict at all with AFOTEC or any OT&E organization. The DODIIS testing does not replace, and in some cases has been done in coordination with formal OT&E conducted by the various responsible service organizations. Joint Collection Management Tool (JCMT) is an example. AFOTEC came to the JITF to prepare for an OT&E they were going to be conducting at an operational site, and participated in the Y2K ISR testing done here last year.

It has been noted that better communication and coordination with the various service OT&E orgs needs to be developed. INSCOM has participated in the DODIIS Test Study (ARMY OT&E). The DODIIS Test Study is the need to involve ALL testers throughout the software lifecycle. DODIIS has the Air Force and Army directives and regulations on testing, which mesh very well with how DODIIS does/”plans to do” business.

Initial Distribution

Headquarters Air Force

SAF/OS	Secretary of the Air Force
AF/CC	Chief of Staff
AF/CV	Vice Chief of Staff
AF/CVA	Assistant Vice Chief of Staff
AF/HO	Historian
AF/ST	Chief Scientist
AF/SC	Communications and Information
AF/SG	Surgeon General
AF/SF	Security Forces
AF/TE	Test and Evaluation

Assistant Secretary of the Air Force

SAF/AQ	Assistant Secretary for Acquisition
SAF/AQ	Military Director, USAF Scientific Advisory Board
SAF/AQI	Information Dominance
SAF/AQL	Special Programs
SAF/AQP	Global Power
SAF/AQQ	Global Reach
SAF/AQR	Science, Technology and Engineering
SAF/AQS	Space and Nuclear Deterrence
SAF/AQX	Management Policy and Program Integration
SAF/MI	Assistant Secretary (Manpower, Reserve Affairs, Installations & Environment)
SAF/SN	Assistant Secretary (Space)
SAF/SX	Deputy Assistant Secretary (Space Plans and Policy)

Deputy Chief of Staff, Air and Space Operations

AF/XO	DCS, Air and Space Operations
AF/XOC	Command and Control
AF/XOI	Intelligence, Surveillance, and Reconnaissance
AF/XOJ	Joint Matters
AF/XOO	Operations and Training
AF/XOR	Operational Requirements

Deputy Chief of Staff, Installations and Logistics

AF/IL	DCS, Installations and Logistics
AF/ILX	Plans and Integration

Deputy Chief of Staff, Plans and Programs

AF/XP	DCS, Plans and Programs
AF/XPI	Information and Systems
AF/XPM	Manpower, Organization and Quality
AF/XPP	Programs
AF/XPX	Strategic Planning
AF/XPY	Analysis

Initial Distribution (continued)

Deputy Chief of Staff, Personnel

AF/DP	DCS, Personnel

Office of the Secretary of Defense

USD (A&T)	Under Secretary for Acquisition and Technology
USD (A&T)/DSB	Defense Science Board
DARPA	Defense Advanced Research Projects Agency
DIA	Defense Intelligence Agency
DISA	Defense Information Systems Agency
BMDO	Ballistic Missile Defense Organization

Other Air Force Organizations

AC2ISRC	Aerospace Command, Control, Intelligence, Surveillance, and Reconnaissance Center
ACC	Air Combat Command
– CC	- Commander, Air Combat Command
– 366th Wing	- 366th Wing at Mountain Home Air Force Base
AETC	Air Education and Training Command
– AU	- Air University
AFMC	Air Force Materiel Command
– CC	- Commander, Air Force Materiel Command
– EN	- Directorate of Engineering and Technical Management
– AFRL	- Air Force Research Laboratory
– SMC	- Space and Missile Systems Center
– ESC	- Electronic Systems Center
– ASC	- Aeronautics Systems Center
– HSC	- Human Systems Center
– AFOSR	- Air Force Office of Scientific Research
AFOTEC	Air Force Operational Test and Evaluation Center
AFSAA	Air Force Studies and Analyses Agency
AFSOC	Air Force Special Operations Command
AFSPC	Air Force Space Command
AIA	Air Intelligence Agency
AMC	Air Mobility Command
NAIC	National Air Intelligence Center
NGB/CF	National Guard Bureau
PACAF	Pacific Air Forces
USAFA	U.S. Air Force Academy
USAFE	U.S. Air Forces in Europe

U.S. Army

ASB	Army Science Board

U.S. Navy

NRAC	Naval Research Advisory Committee
Naval Studies Board	

Initial Distribution (continued)

U.S. Marine Corps

DC/S (A)	Deputy Chief of Staff for Aviation

Joint Staff

JCS	Office of the Vice Chairman
J2	Intelligence
J3	Operations
J4	Logistics
J5	Strategic Plans and Policies
J6	Command, Control, Communications, and Computer Systems
J7	Operational Plans and Interoperability
J8	Force Structure, Resources and Assessment

Other

Aerospace Corporation
ANSER
MITRE
RAND
Study Participants

(This Page Intentionally Left Blank)

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and manipulating the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget Paperwork Reduction Project (0704-0188), Washington, DC 20503

1. AGENCY USE ONLY (*Leave Blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 2000	Final, January 2000 - November 2000

4. TITLE AND SUBTITLE
Air Force Command and Control: The Path Ahead, Volume 2, Panel Reports

5. FUNDING NUMBERS

6. AUTHOR(S)
Dr. Peter R. Worch, Gen James P. McCarthy, USAF (Ret), Lt Gen Joseph E. Hurd, USAF (Ret), Dr. John M. Borky, Dr. Alison K. Brown, Maj Gen Eric B. Nelson, USAF (Ret), Mr. Jeffery B. Erickson, Mrs. Natalie W. Crawford

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES)
AF/SB
Pentagon
Washington, DC 20330-1180

8. PERFORMING ORGANIZATION REPORT NUMBER
SAB-TR-00-01

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
SAF/OS
AF/CC
Pentagon
Washington, DC 20330-1670

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Cleared for Open Publication

12b. DISTRIBUTION CODE

ABSTRACT (Maximum 200 Words)

Air Force Command and Control: The Path Ahead

Air Force Chiefs of Staff have chartered numerous studies and conducted four star reviews in their attempts to "fix" the Air Force C^2 problem. Air Force Chiefs of Staff also established a new Air Staff C^2 Directorate, an Air Staff C^2 General Officer Steering Group, and the Aerospace C^2 Intelligence, Surveillance and Reconnaissance Center in their attempts to "fix" C^2.

The lessons learned from DESERT STORM and ALLIED FORCE and the results of every Air Force SAB and Defense Science Board study have determined that U.S. aerospace power capabilities continue to outperform the associated C^2 capabilities. In theater C^2 this is particularly evident in time critical targeting, battle damage assessment, and campaign assessments.

The Air Force vision of "well-equipped C^2 centers collaborating globally in support of the CINCs" can be rapidly achieved if senior Air Force leadership strongly endorses the need for an enterprise-wide C^2 capability. The Air Force must restructure the way C^2 programs are managed and resourced, and leadership must clearly speak out about their dedication to achieving an enterprise-wide C^2 capability at every opportunity..

14. SUBJECT TERMS
Battlespace InfoSphere, C^4I, command and control, decision support tools, combat support, battlespace awareness, information management, information access, information grid, information manipulation, collaboration, interoperability, system acquisition, air expeditionary forces, joint operations

15. NUMBER OF PAGES
554

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	None

(This Page Intentionally Left Blank)